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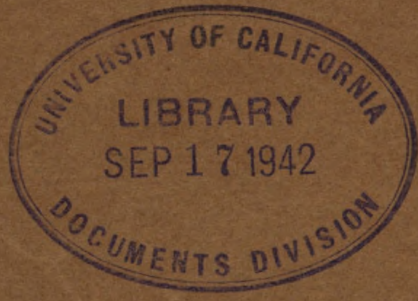
U.S. Army

WAR DEPARTMENT

TECHNICAL MANUAL

AUTOMOTIVE BRAKES

March 8, 1941



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WAR DEPARTMENT,
WASHINGTON, March 8, 1941.

AUTOMOTIVE BRAKES

Prepared under direction of
The Quartermaster General

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MECHANICS

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1. **Purpose.**—The purpose of the braking system is to reduce the speed of a vehicle or to stop the vehicle and hold it in place when stopped. Brakes must be so designed that they will readily retard a vehicle without causing the wheels to slip or skid. The importance of the braking system has been emphasized in recent years because of increased vehicle speeds. Present day demands for safe, rapid deceleration have led to the development of effective and dependable braking systems.

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2. Terminology.—For purpose of clarity and ready reference the following terms are defined:

Accelerate.—To increase velocity or speed, as from 20 to 30 miles per hour.

Atmospheric pressure.—Pressure exerted in all directions upon all objects on the earth by the weight of air above the earth's surface. At sea level this pressure is 14.7 pounds per square inch.

Braking action.—Use of a controlled force to reduce the speed of or stop a moving vehicle, or to keep a vehicle stationary.

Coefficient of friction.—Ratio between the force required to move one surface over another and the pressure holding these surfaces together.

Decelerate.—To decrease velocity or speed, as from 30 to 20 miles per hour.

Electromagnet.—Magnet formed by passing a current of electricity through wire wound around a core (usually of soft iron).

Energy.—Capacity for doing work. Measured in work units.

Friction.—Resistance to relative motion between two surfaces in contact.

Fulcrum.—Support about which a lever turns.

Hydraulics.—Science of using liquids under pressure to do work.

Hydraulic pressure.—Pressure exerted by a liquid.

Kinetic energy.—Energy of motion. Increases with the square of the speed, and is the energy that must be overcome by the application of brakes.

Lever.—Rigid bar or beam of any shape capable of turning about one point called a fulcrum. Used for transmitting or modifying force or motion.

Leverage.—Mechanical advantage obtained by use of a lever; also an arrangement or combination of levers.

Linkage.—Any system of links or levers joined together.

Load arm.—Perpendicular distance on a lever from the direction of the load to the fulcrum.

Mechanical advantage.—Ratio of the force applied through use of mechanical means such as levers or gears to resistance to be overcome.

Mechanics.—Study of the action of force on bodies.

Mechanism.—System of parts or appliances which act as working agency to produce desired effect.

Power.—Rate at which work is done by transfer of energy.

Power arm.—Perpendicular distance on a lever from the direction of applied force to the fulcrum.

Reaction time.—Time elapsed between noting warning signal and taking the necessary action. For example, the time it takes a driver to apply the brake after the need of stopping is apparent.

Retard.—To slow down or to impede progress.

Self-energizing action.—Wedging action produced by nonrotating braking service forced against its support by rotating braking surface.

Vacuum.—Commonly termed a space from which air or gas has been partly exhausted resulting in a pressure below atmospheric pressure. A perfect vacuum, one from which all matter has been removed, resulting in no weight or pressure whatsoever, is not obtainable.

3. Action.—Braking action is the use of a controlled force to reduce the speed of or stop a moving vehicle, or to keep a vehicle stationary. When the braking force is applied it develops friction, which does the braking. Friction is the resistance to relative motion between two surfaces in contact. Thus by forcing a stationary surface into contact with a surface on a revolving wheel of a moving vehicle, the resistance to relative motion or the rubbing action between the two surfaces will slow down the wheel and retard the vehicle. Automotive vehicles are braked in this manner. Braking action may also be accomplished by establishing a rubbing contact with the roadway as is done by some trolleys which apply a braking surface to the rails.

4. Requirement.—*a.* Vehicle operators usually realize that to increase a vehicle's speed requires an increase in the power output of the engine. It is equally true although not so apparent that an increase in speed requires an increase in the braking action necessary to bring a vehicle to a stop. A vehicle, just as any other body, has energy due to its motion known as kinetic energy. This kinetic energy, which increases with the square of the speed, must be overcome by braking action. If the speed of a vehicle is doubled, its kinetic energy is increased fourfold; four times as much energy must therefore be overcome by the braking action.

b. Brakes must not only be capable of stopping a vehicle but must stop it in as short a distance as possible. The faster kinetic energy is overcome, the more is the power required. Because brakes are expected to decelerate a vehicle at a faster rate than the engine can accelerate it, they must be able to control a greater power than that developed by the engine. This is the reason why well-designed, powerful brakes have to be used to control the modern high speed motor vehicle. A comparison between the horsepower developed by

the engine and the horsepower required by the brakes of a passenger car is shown in figure 1.

c. It is possible to accelerate an average passenger car with an 80-horsepower engine from a standing start to 80 miles an hour in 36 seconds. By applying the full force of the brakes, such a vehicle can be decelerated from 80 miles an hour to a full stop in 4.5 seconds. The time required to decelerate to a stop is one-eighth the time required to accelerate from a standing start, hence the brakes handle eight times the power developed by the engine. Thus, about 640 (8×80) horsepower has to be expended by the friction surfaces of

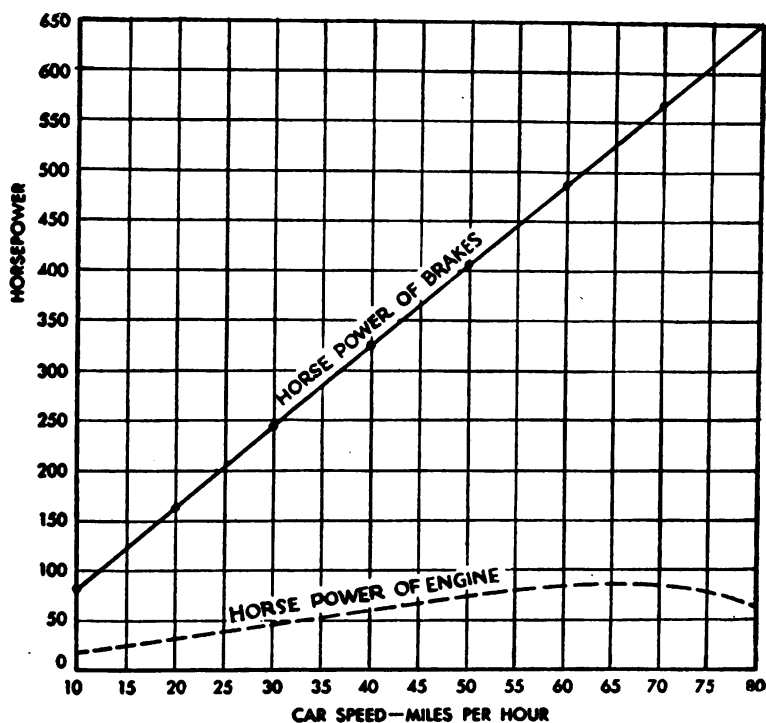


FIGURE 1.—Comparison of horsepower developed by engine and horsepower required by brakes on passenger car.

the brakes of an average passenger car to bring it to a stop from 80 miles an hour in 4.5 seconds.

5. **Stopping distance.**—Because of the physical laws of nature, no vehicle can be decelerated by brakes quicker than a definite rate even under ideal conditions. Therefore the minimum distance in which a vehicle can be stopped by brakes at any definite speed is limited. During the time that the driver is thinking of applying the brakes and moving his foot to do so the vehicle has moved a certain distance, depending on its speed. This time required for a mental response before the brakes are actually applied is the driver's re-

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action time. Thus, total stopping distance of a vehicle is the total of the distance covered during driver's reaction time and the distance during which brakes are applied before the vehicle stops. Figure 2 gives total stopping distance required at various vehicle speeds, assuming an average reaction time of three-fourths second and that good brakes are applied under most favorable road conditions.

6. Levers.—*a.* The force exerted or controlled by the driver in applying brakes is increased by use of a lever, irrespective of the system of braking used. The lever, a simple machine, is a rigid bar or beam of any shape capable of turning about one point called a fulcrum and containing points for applying force. The fulcrum may be at any point on the lever depending upon how the force is to be applied. Figure 3① illustrates action of a lever. On the brake pedal lever the fulcrum is usually located at one end and the force

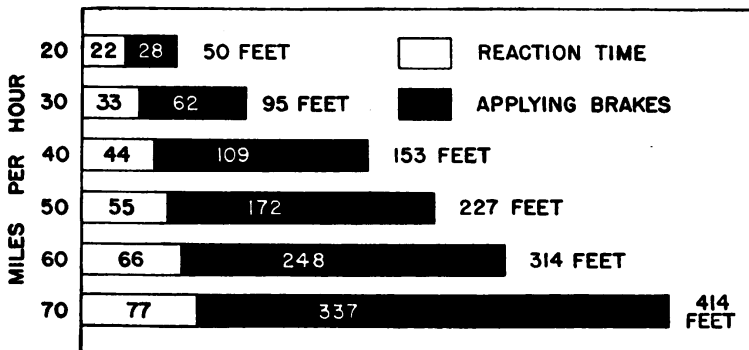


FIGURE 2.—Total stopping distance of vehicle.

is applied to the pedal on the other, as in figure 3② in which the load is between the fulcrum and the point at which the force is applied. The bar in figure 3① demonstrates action that occurs at the brake pedal.

b. The perpendicular distance from the direction of force to fulcrum is called the power arm. The perpendicular distance from the direction of load to fulcrum is called the load arm.

c. A small force can overcome a much larger resisting force or load with the aid of a lever. The force required to overcome the load depends upon the mechanical advantage of the lever. The mechanical advantage obtained from a lever depends upon the ratio of power arm to load arm. Thus if the ratio of power arm to load arm is 4 to 1, only one-quarter of the resisting force of the load is required at the end of the power arm to overcome the load. The mechanical advantage to be gained by use of a lever is shown in figure 4.

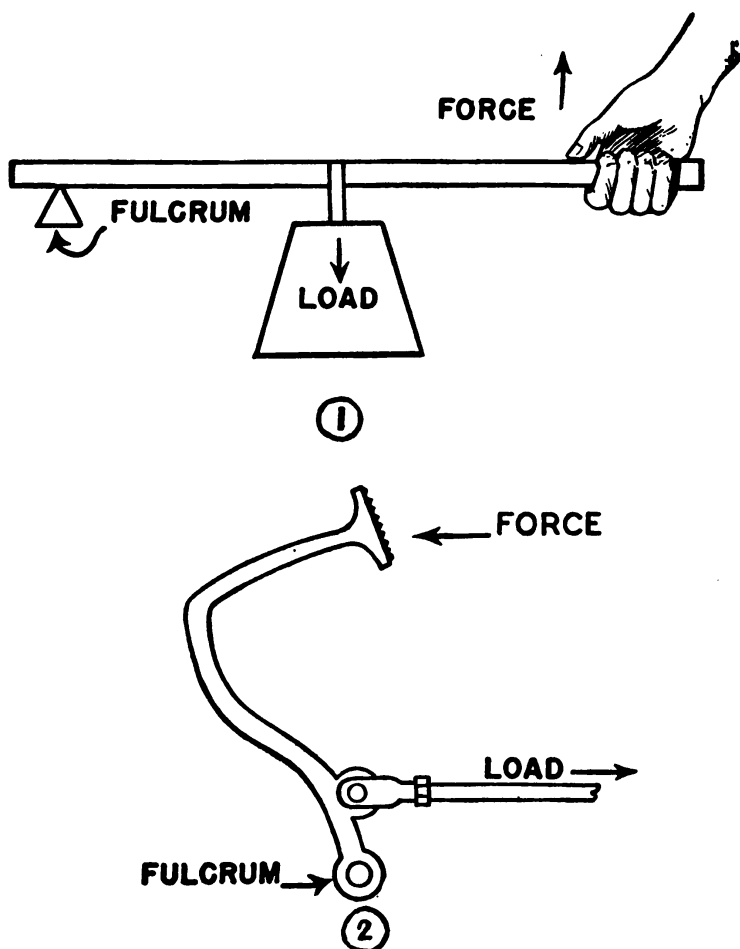


FIGURE 3.—Type of lever used for brake pedal.

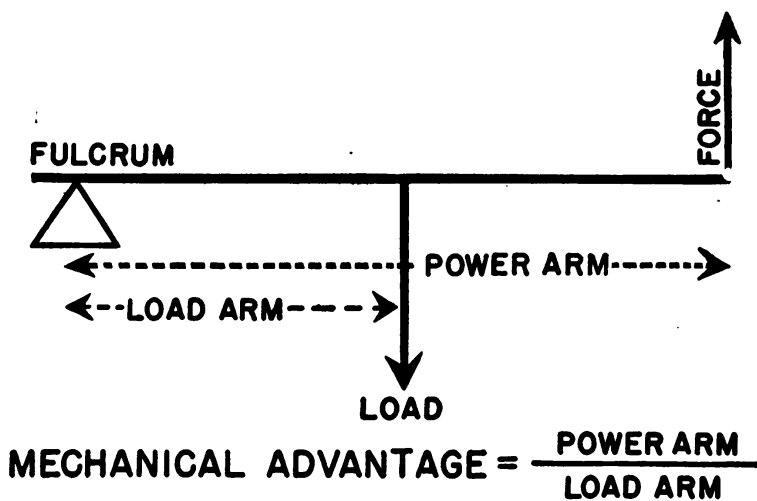


FIGURE 4.—Mechanical advantage of lever.

d. Length of the power arm varies with the angle between the line of applied force and the lever. Thus length of the power arm varies with position of lever as shown in figure 5. The power arm P reaches its greatest length when the lever is perpendicular (square) to the line of applied force. The brake system operates most effectively if each lever is set so that the power arm reaches its greatest length

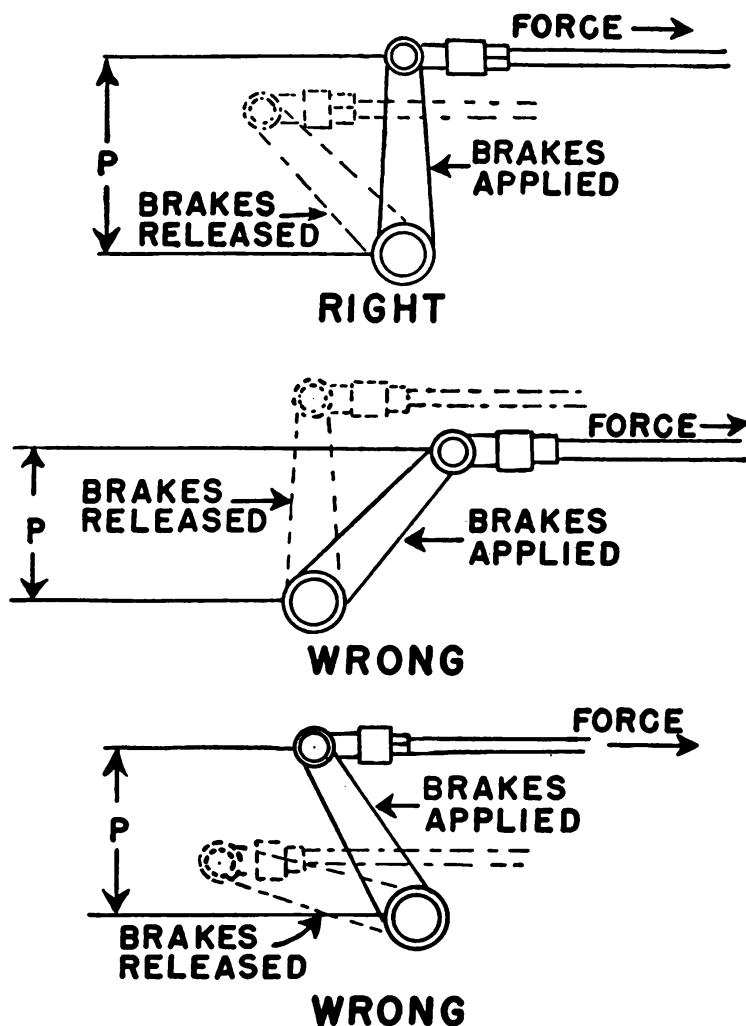


FIGURE 5.—Proper lever adjustment.

(lever is perpendicular to the force) when brakes are fully applied. The greatest mechanical advantage is then obtained from the system when it is most needed, that is, at full application of the brakes.

7. **Friction.**—a. *Amount.*—Value of the friction used for braking action depends upon the design of the brake. The two outstanding factors that govern the amount of friction developed between two

surfaces in contact are pressure holding the surfaces together and materials used for the surfaces. The more pressure applied the tighter the surfaces will grip each other and resist any relative motion. Rough-surfaced materials will grip and resist relative movement more than smooth-surfaced materials. For instance, there is a great deal of friction between a tire and dry pavement while there is very little friction between a tire and ice.

b. Coefficient.—The coefficient of friction is the ratio between the force required to move one surface over another and the pressure holding these surfaces together. For example, if it requires a force of 400 pounds to move a box weighing 1,000 pounds over a concrete floor, the coefficient of friction between box and floor is $\frac{400}{1000} = 0.4$. As another example, suppose that the weight on one wheel of a vehicle is 750 pounds and that a force of 350 pounds acting on the tread of the tire is required to lock the wheel so that it will skid on the road. Coefficient of friction between the tire and the road is then $\frac{350}{750} = 0.466$. The higher the coefficient of friction between two surfaces the greater is the amount of friction developed between them.

c. Design factor.—When any two surfaces move against each other, the friction between them develops heat and tends to wear them away. By increasing contact area between two surfaces effect of friction is spread, thereby preventing excessive heat and wear over a small area. The factors resulting from friction as well as those affecting the amount have to be taken into account when designing a braking system.

8. Factors affecting retardation.—*a.* The amount of retardation obtained by the braking system of a vehicle is affected by several factors. For wheel brakes used on motor vehicles these are—

- (1) Pressure exerted on braking surfaces (lining and drum).
- (2) Weight carried on wheel.
- (3) Overall radius of wheel (distance from center of wheel to outer tread of tire).
- (4) Radius of brake drum (rotating member).
- (5) Coefficient of friction between braking surfaces.
- (6) Coefficient of friction between tire and road.

b. For a definite amount of retardation, exerted pressure required on braking surfaces will become greater when weight carried on the wheel or overall radius of the wheel is increased. These factors are not affected by the design of the braking system and are generally a fixed value. However, limitations of these factors, particularly the weight of the vehicle to be carried by the wheel, must

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be considered when designing a braking system. If radius of the brake drum or coefficient of friction between braking surfaces is increased, less pressure will be required to obtain the same degree of retardation. To give the best results, these factors are changed within certain limits by the design of the braking system. The coefficient of friction between tire and road determines maximum retardation obtained by the application of brakes.

9. Maximum retardation point.—*a.* When brakes are applied the wheel will either roll or skid, depending on relative values of coefficients of friction between braking surfaces and between tire and road. Rapidly jamming the braking surfaces together will tend to increase the friction to such a degree that the wheel will lock and skid along the road. When this happens braking action is caused by friction between tire and road, which heats and wears the tire. If brakes are applied at the same even rate on a dry

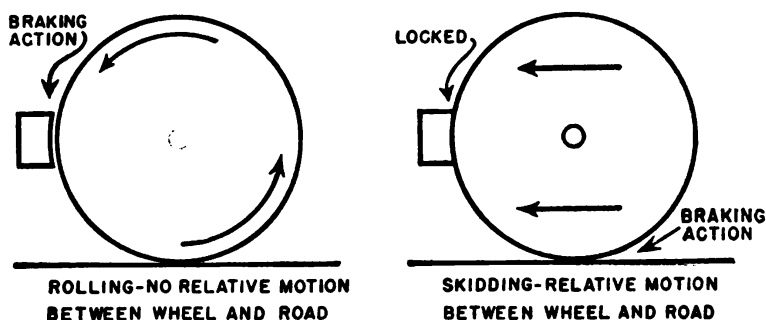


FIGURE 6.—Action produced when wheel rolls or skids.

pavement and on ice, causing the same friction between lining and drum, the wheel will ordinarily roll on the dry pavement, but on the ice it is apt to skid because of the lower coefficient of friction between tire and ice.

b. Maximum retardation is reached when friction between the brake surfaces is such that the wheel is about to lock. At this point friction between the brake surfaces is almost the same as that between tire and road. This is the maximum amount of friction that can be used in retarding motion of the car. Friction encountered between tire and road is the limiting factor of braking. Should friction between braking surfaces go beyond this, the braking surfaces will lock and the wheel will skid. The action produced when a wheel rolls and when it skids is shown in figure 6. When a wheel rolls along a road there is no relative motion at the point the tire makes contact with the road because the wheel rolls with the road surface, but when a wheel skids there is relative motion at the point of con-

tact because the wheel is not rotating while moving over the road surface. When a wheel skids friction is reduced, which decreases the braking effect. The maximum retardation point is an important factor to consider in design, adjustment, and use of brakes.

SECTION II

MECHANISMS

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10. Rotating and nonrotating units.—*a.* Brake mechanisms may be of various designs but they all require a rotating unit and a nonrotating unit, each containing one of the braking surfaces that are rubbed together to achieve the braking action.

b. One of the earliest means of braking is the wagon wheel brake shown in figure 7. In this brake the wheel is the rotating unit and the wheel rim is the braking surface. The nonrotating unit is the brake shoe which is supported on a arm operated by a lever.

c. The rotating unit on motor vehicle wheel brakes consists of a drum secured to the wheel. The nonrotating unit consists of brake shoes and linkage necessary to apply the shoes to the drum. Brakes are either of the external contracting or internal expanding type, depending on how the nonrotating braking surface is forced against the rotating braking surface.

11. External contracting brake.—*a.* When brake shoes or a brake band is applied against the outside of the rotating brake drum, the brake is known as an external contracting type since the nonrotating braking surface must be forced inward around the drum to produce the friction necessary for braking. A brake using an external contracting band is shown in figure 8. The brake band is tightened around the drum by moving the brake lever.

b. Unless an elaborate cover is provided, the external contracting brake is exposed to dirt, water, and other foreign matter which rapidly wears the lining and drum and destroys their frictional properties. This is particularly true with wheel brakes.

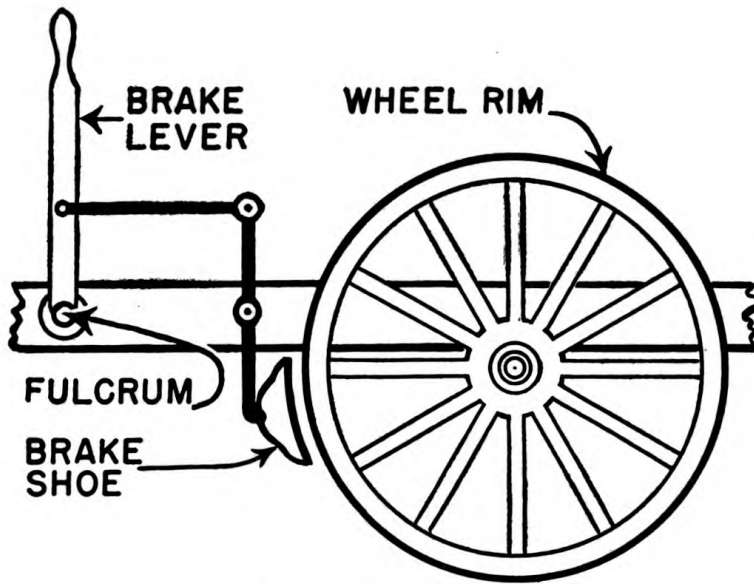


FIGURE 7.—Wagon wheel brake.

12. Internal expanding brake.—The nonrotating unit may be placed inside the rotating drum with the drum acting as a cover for the braking surfaces. This type of brake is known as an internal expanding brake because the nonrotating braking surface is forced outward against the drum to produce braking action. A brake using internal expanding shoes is shown in figure 9. This type of brake is used on the wheel brakes of the modern motor vehicle because it permits a more compact and economical construction. The brake

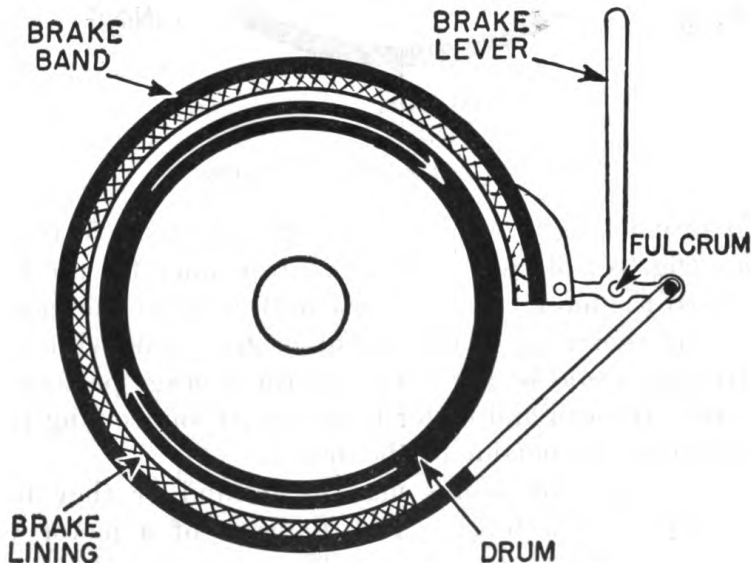


FIGURE 8.—External contracting brake.

shoes and brake operating mechanism may be conveniently mounted on a backing plate or brake shield made to fit against the open end of the brake drum and protect the braking surfaces from dust and other foreign matter.

13. **Drum.**—*a.* Brake drums are made of pressed steel, cast iron, or a combination of the two metals. Cast-iron drums dissipate the heat generated by friction more rapidly than steel drums and have a higher coefficient of friction with any particular brake lining. However, cast-iron drums of sufficient strength are heavier than steel

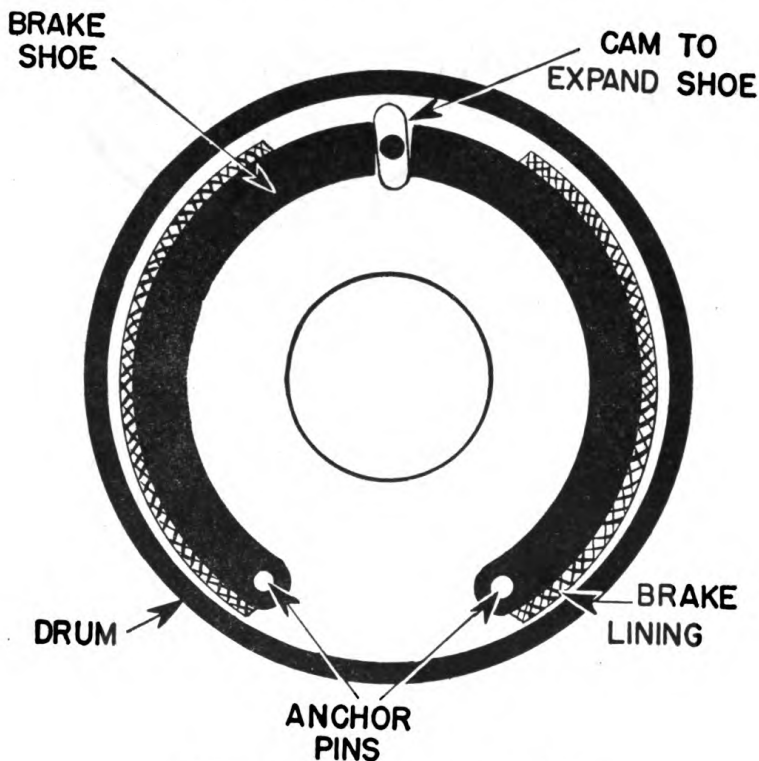


FIGURE 9.—Internal expanding brake.

drums. To provide light weight and sufficient strength centrifuse brake drums (fig. 10) of steel with a cast-iron liner for the braking surface are used the most. A solid cast-iron drum of the same total thickness as the centrifuse drum would be too weak while one of sufficient strength would be too heavy for the average passenger car. To give greater strength and better heat dissipation, cooling ribs are sometimes added to the outside of the drums.

b. Braking surfaces of drums may be ground or they may be smoothly machined to a finish. The diameter of a motor vehicle brake drum is usually between 9 and 18 inches, and the faces are up to 3 inches wide.

c. For good braking action the drum should be perfectly round and have a uniform surface. Brake drums become "out of round" due to pressure exerted by brake shoes or bands and due to heat developed by application of the brakes. The brake drum surface becomes scored when it is worn by braking action. When the surface is badly scored or the drum more than .010 inch out of round, it is necessary to replace the drum or regrind it or turn it down in a lathe until the drum is again smooth and true. Care must be taken that the drums do not become too thin as pressure exerted by the brake band or shoe may distort them or cause a severe squeak. Experience indicates that brake drums should be replaced if the thickness is reduced below the minimum indicated in the following table.

Drum diameter	Minimum thickness of material		
	Steel	Centrifuse	Cast-iron
<i>Inches</i>	<i>Inch</i>	<i>Inch</i>	<i>Inch</i>
9-----	0. 115	0. 145	-----
10-----	. 115	. 145	-----
11-----	. 115	. 145	-----
12-----	. 140	. 170	0. 230
13-----	. 140	. 170	. 230
14-----	. 150	. 180	. 240
15-----	. 180	. 215	. 275
16-----	. 190	. 220	. 280

14. Shoe.—a. Brake shoes are made of malleable iron, cast steel, drop forged steel, pressed steel, or cast aluminum. Pressed steel is generally used because it is cheaper to produce in large quantities. Steel shoes expand about the same rate as the drum when heat is generated by brake application, thereby maintaining the clearance between the brake drum and shoe under most conditions.

b. A friction lining riveted to the face of the shoe makes contact with the inner surface of the brake drum. Semitubular brass rivets are used because brass does not unduly score the drums when the lining is worn. Aluminum rivets are not very satisfactory because they corrode very easily if they come in contact with salt water.

c. It is not always necessary to rivet the lining to the shoes. In some brakes the lining is not fastened to either the shoes or the drum, but floats between them and is held in place by a lining retainer on one side and the brake shield on the other.

15. Lining.—*a. Type.*—Variation in brake design and different conditions of operation make it necessary to have various types of brake lining. Woven and molded brake linings are generally used on automotive vehicles.

b. Woven.—(1) Woven lining (fig. 11) is made of large yarns or cords of asbestos fiber, long cotton fiber, and bronze or copper wire. After being woven into a strip of the desired width, the lining is impregnated with treating compounds (usually tars or gums) which render it almost impervious to oil and water, thus reducing effects of

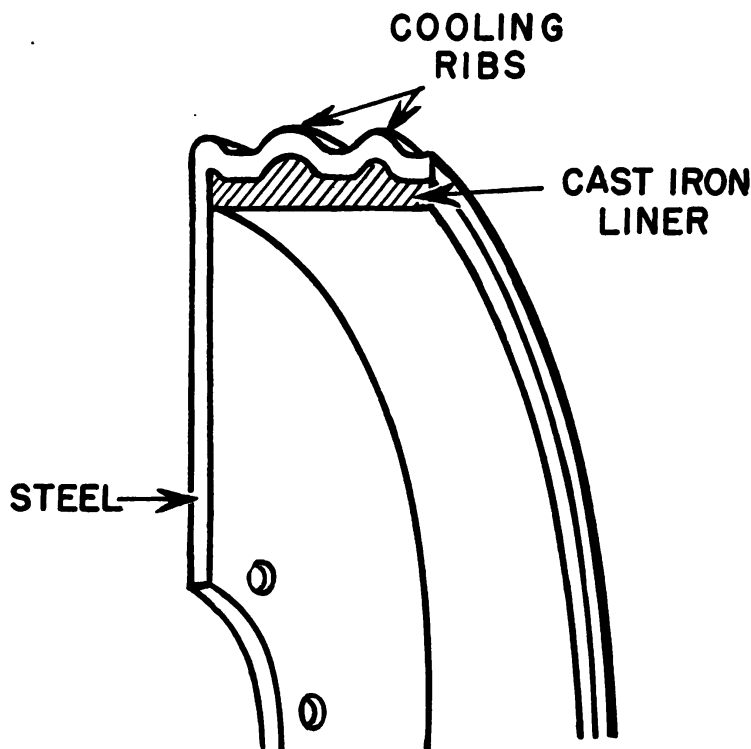


FIGURE 10.—Centrifuse brake drum.

these liquids on frictional qualities of the lining. After impregnation the lining is compressed and heat-treated.

(2) Heat and wear resisting qualities of the lining as well as its coefficient of friction depend upon method and materials used for treating and impregnating the fabric base. These materials should not carbonize at low temperatures or the lining will become glazed and the coefficient of friction will be reduced to the point where the brakes will lose their effectiveness.

c. Molded.—(1) Molded lining (fig. 12) is made of materials which are hard, dense, and compact. The linings are produced in metal molds or dies. Molded lining is cut in blocks to fit various brake

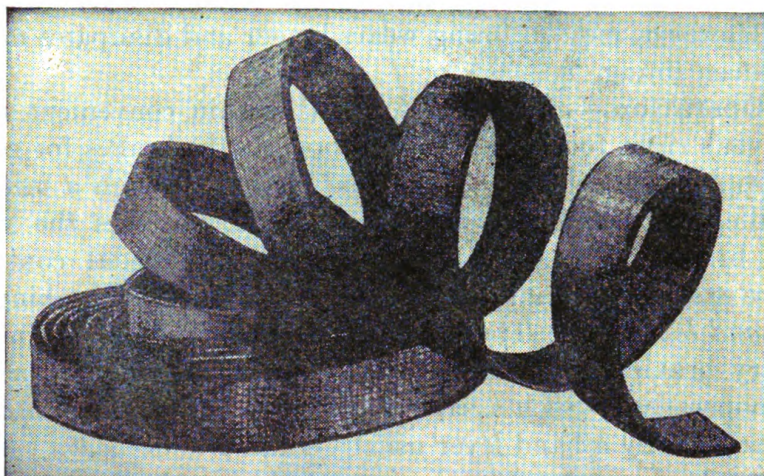


FIGURE 11.—Woven brake lining.

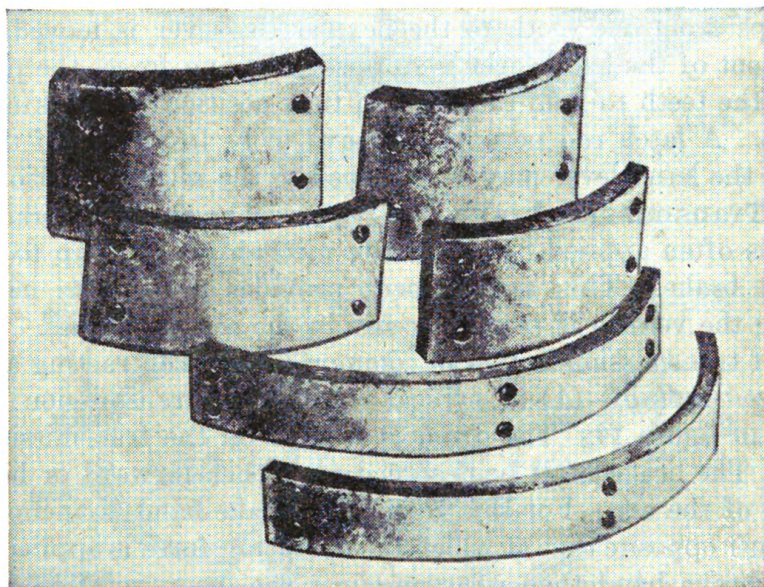


FIGURE 12.—Molded brake lining.

shoes for which it is suited or in coils cured to various drum diameters.

(2) Molded lining usually does not have as high a coefficient of friction as woven lining because it does not have as irregular a surface. However, molded lining wears longer and dissipates more heat than woven lining.

16. Operation.—*a. Pedal.*—A pedal within convenient reach of the driver's right foot is provided to operate the brakes for retarding and stopping the vehicle. This pedal, acting through a mechanical, hydraulic, air, vacuum, or electric medium, operates the wheel or service brakes. Pressure applied on the foot pedal controls the pressure exerted on braking surfaces to obtain desired braking action.

b. Hand lever.—(1) The braking system should be designed so an auxiliary braking mechanism is available if the service brakes become inoperative. Such a safeguard is provided by a brake mechanism operated by a hand lever usually located underneath the instrument panel, or on the driver's right alongside the gear shift lever. This brake mechanism is also used to provide a parking brake.

(2) The hand lever contains a ratchet and pawl arrangement that allows the auxiliary brakes to be set in any position. This arrangement consists of a sector or strip of metal into which are cut ratchet teeth (see fig. 13). The pawl is fastened to the hand lever so that it jumps from one tooth to the next as the lever is moved. When movement of the hand lever is stopped, a spring forces the pawl into one of the teeth to hold the lever in that position for parking of the vehicle. A latch rod permits the pawl to be lifted out of the tooth so that the hand lever may be returned to the release position.

17. Transmission brake.—*a. Types.*—The auxiliary brake mechanism is often applied by a separate mechanical hook-up to a transmission brake. This arrangement provides a separate means for braking the vehicle if trouble occurs in the service brakes. The two types of transmission brakes in common use are contracting and disk.

b. Contracting.—(1) A typical contracting transmission brake is shown in figure 14. The drum is splined on the transmission main shaft. The brake must be designed for either forward or backward motion of the car. For this reason the brake band is anchored at a point just opposite that at which the operating force is applied. Half of the brake band then wraps against the drum rotation in either direction.

(2) The mechanism for operating this brake is usually a simple bell crank arrangement controlled by the hand lever. A spring disengages the brake band lining when the actuating pressure is released.

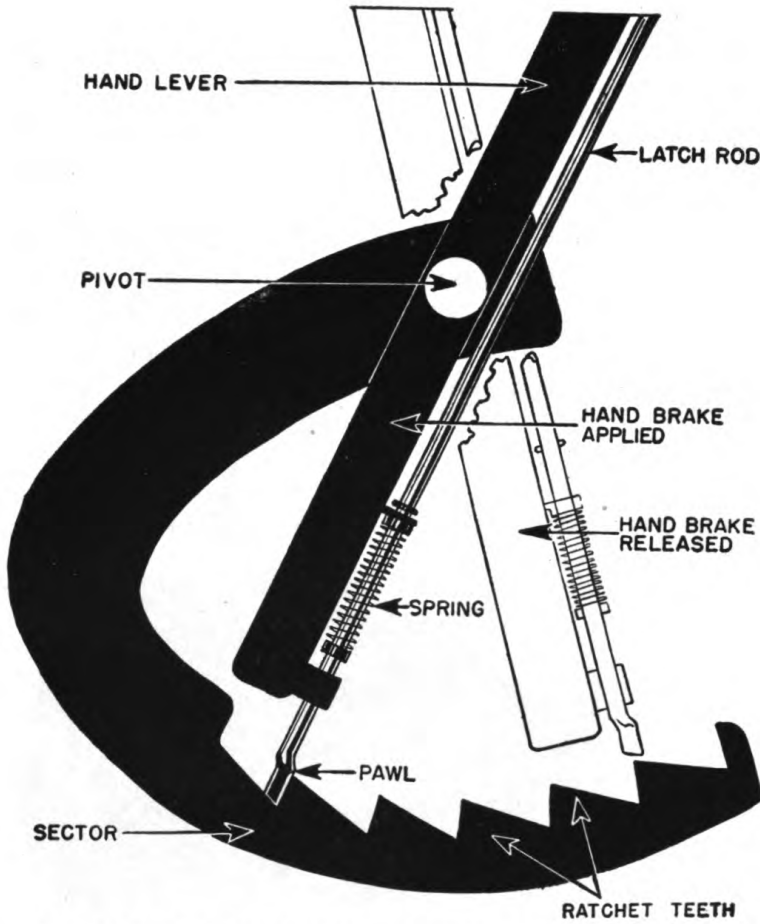


FIGURE 13.—Ratchet and pawl arrangement on brake hand lever.

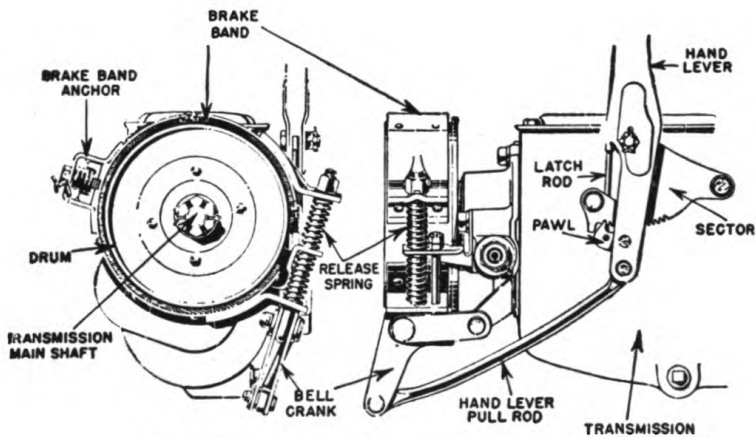


FIGURE 14.—Contracting transmission brake.

Various other mechanisms are employed for operating contracting transmission brakes.

c. Disk.—The disk brake is generally mounted on the rear of the transmission case or on a cross member of the frame. It is designed to dissipate rapidly the heat generated in braking. The rotating member of the brake (see fig. 15) consists of a specially designed steel disk splined to the transmission main shaft. This disk has two faces which act as the rotating braking surface. Between them are air passages so arranged that a large volume of air passes through them to cool the braking surface when the disk is rotating. One brake shoe covers one-fourth of each disk face. The shoes are supported on swinging brackets and are clamped against the disk faces by

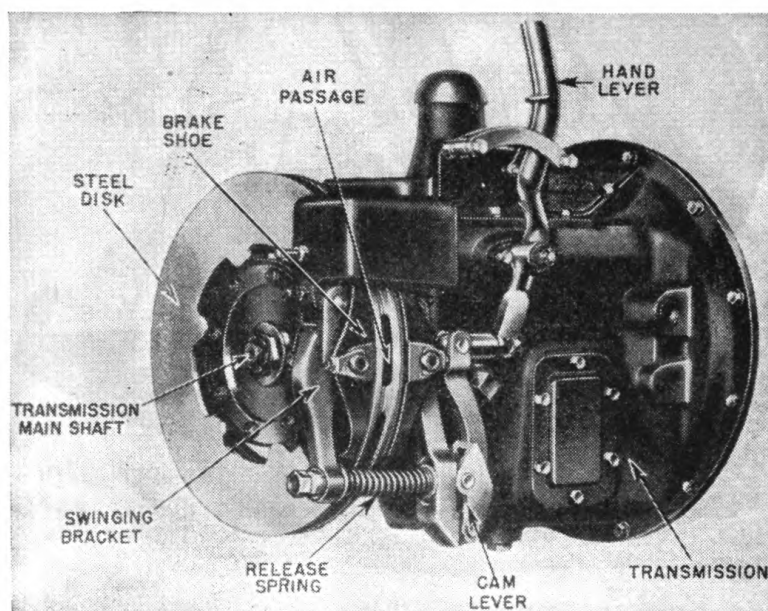


FIGURE 15.—Disk transmission brake.

means of a camlever arrangement. A spring removes the shoes from the disk faces when the hand lever is released.

d. Advantages and disadvantages.—Transmission brakes are very easy to operate. For any given amount of actuating pressure transmission brakes give greater braking effect due to gear reduction in rear axle. Since the retarding effect of the transmission brake is transmitted to the driving wheels through the differential gear, it is always automatically equalized between the wheels. Location of the brake protects it from most of the road dust and dirt, and since it is attached to the transmission or frame it benefits from the cushioning effect derived from the vehicle springs. The possible width of a brake

drum of the contracting type is almost unlimited. However, the location of this brake compared with that of wheel brakes is unfavorable for cooling purposes, a very important consideration. Moreover, the diameter of the rotating members is limited, generally as much or more than that of the wheel brakes.

18. Wheel brake.—*a.* The wheel or service brakes used for retarding and stopping modern motor vehicles operate on all four wheels. Early motor vehicles had wheel brakes on the two rear wheels only, but this practice is obsolete. Four-wheel brakes give increased braking effect and also make possible a much smoother, more even braking action, thereby reducing the tendency to skid. Wheel or service brakes are interconnected so that they may be adjusted to operate together from one control.

b. The method of mounting rotating and nonrotating units of the brake on the wheel is shown in figure 16. The brake drum is mounted directly on to the wheel and provides the rotating braking surface. The brake shield, sometimes called the backing plate or dust shield, is mounted on some fixed structure such as the axle housing, and forms a support for the nonrotating braking surface and its operating mechanism.

c. The brake shoes may be anchored to the brake shield by separate pins or by the same pin. Conical springs usually are used to keep the shoes in position close to the brake shield. A fairly strong retracting spring is hooked between the shoes to pull them away from the drum when the brakes are released (see fig. 19). With a mechanical hook-up pressure can be applied to the brake shoes by means of a cam, toggle, or double lever arrangement. A cam turned by a small lever is the method most frequently used. Turning the cam by the lever tends to spread the brake shoes and push them outward against the drum. The material of the wearing surfaces against which the cam bears must be able to withstand considerable pressure, since lubrication at this point is difficult and since some road grit is certain to find its way into the brake drum. With a hydraulic system, pressure is applied to the brake shoes by means of a wheel cylinder.

19. Self-energizing action.—*a.* The brake-operating linkage alone does not provide sufficient mechanical advantage for positive braking. Some means of supplementing the physical application of the braking system has to be used to increase pressure on the brake shoes. A self-energizing action is very helpful in accomplishing this once setting of the shoes is started by physical effort. While there are variations of this action, it is always obtained by the shoes themselves tending to revolve with the revolving drum.

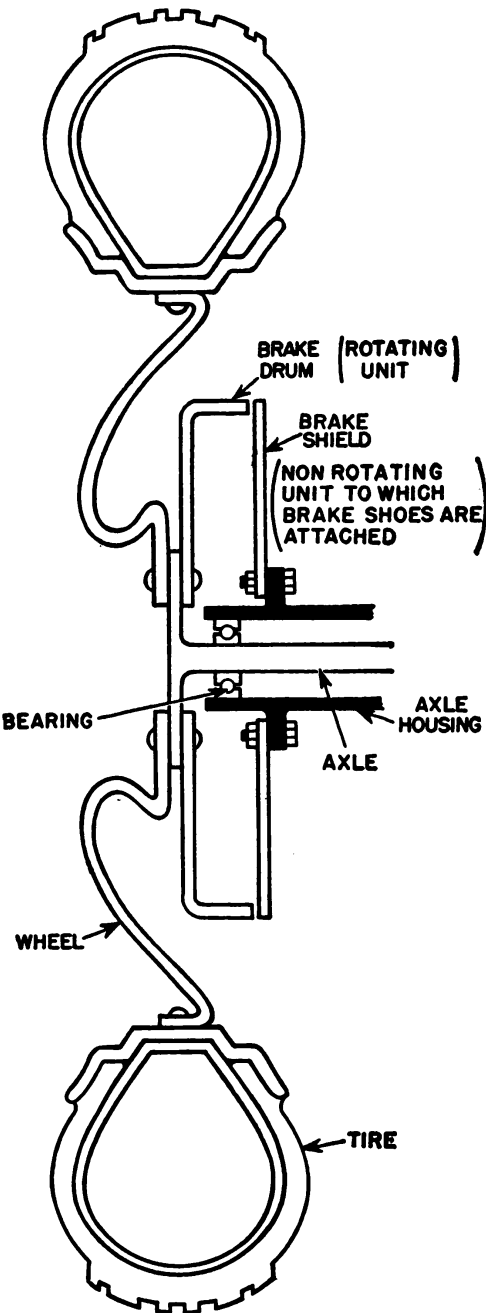


FIGURE 16.—Wheel brake mounting.

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b. When the brake shoe is anchored as shown in figure 17, and the drum revolves in the direction shown, the shoe will try to revolve with the drum when it is forced against the drum. As a result the shoe will exert considerable pressure against the anchor pin. Since the pin is fixed to the brake shield, this pressure will tend to wedge the shoe tightly in between the pin and the drum as shown. As the initial braking pressure is increased on the cam, the wedging action increases and the shoe is forced still more tightly against the drum

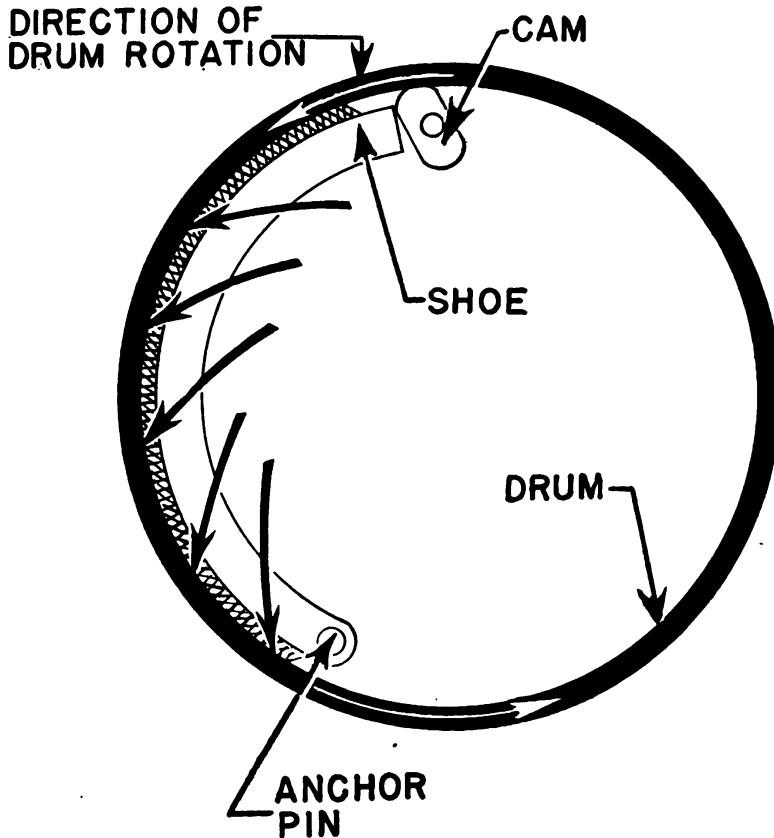


FIGURE 17.—Self-energizing action.

to increase the friction. This self-energization results in more braking action than could be obtained with the actuating pressure alone. Brakes making use of this principle to increase pressures on the braking surfaces are known as self-energizing (sometimes called servo) brakes.

c. It is most important that the operator control the total braking action at all times; therefore, the self-energizing action should increase only upon application of additional actuating pressure at the brake pedal. The amount of self-energizing action available depends

mainly on location of the anchor pin. As the pin is moved toward the center of the drum, wedging action increases until a point is reached where the shoe will automatically lock. The pin must be located outside of this point so that the operator can control the braking.

d. When two shoes are anchored on the bottom of the brake shield, as shown in figure 9, self-energizing action is effective on only one shoe. The other shoe tends to revolve away from its pivot which reduces its braking action. When the wheel is revolving in the opposite direction, the self-energizing action is produced on the opposite shoe.

e. (1) Two shoes are usually mounted so that self-energizing action is effective on both. This is accomplished by pivoting the shoes

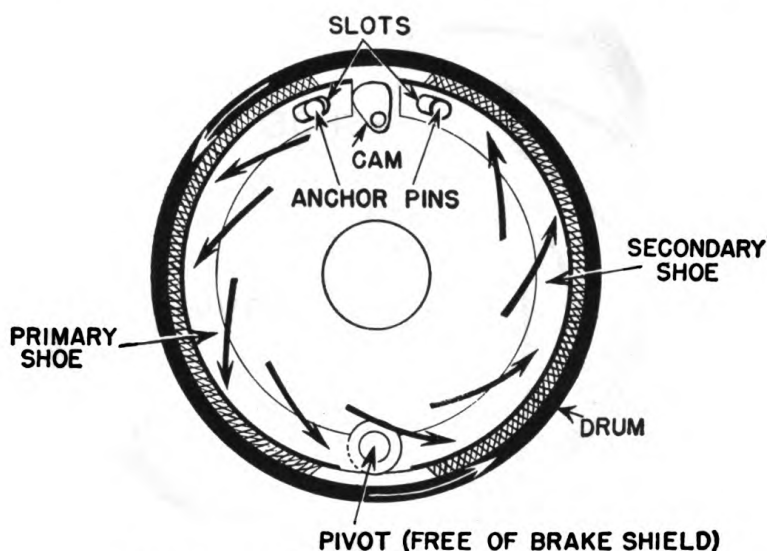


FIGURE 18.—Mounting for two self-energizing shoes.

to each other and leaving the pivot free of the brake shield. The only physical effort required is for operating the first or primary shoe. Both shoes then apply additional pressure to the braking surfaces with no increase in the pressure on the operating linkage. The anchor pins are fitted into slots in the free ends of the brake shoes. This method of anchoring allows the movement of the shoes necessary to expand against the drum.

(2) When the shoes are forced against the drum, the self-energizing action of the primary shoe is transmitted through the pivot to the secondary shoe, as shown in figure 18. Both shoes will tend to revolve with the drum and will be wedged against the drum by the one anchor pin. The other anchor pin will cause a similar action

when the wheel is revolving in the opposite direction. Hence both shoes are self-energizing in either direction.

f. Another type of brake shoe mounting (fig. 19), consists of two links anchored together on the brake shield with the end of each link pivoted to one of the brake shoes. This articulated mounting allows more even application of the braking surfaces because of the freedom of movement of the brake shoes. Each shoe is self-energizing in opposite directions. The amount of self-energization and the degree of control by the operator depend on the anchor position of the links.

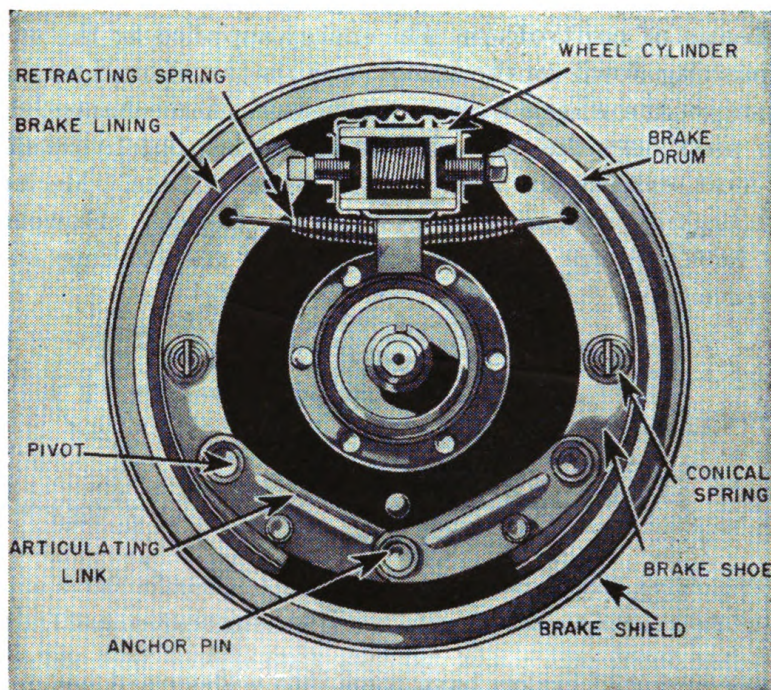


FIGURE 19.—Articulating link wheel brake.

20. Lubrication.—Brake shoe pivots and anchor pins and brake mechanism must be lubricated to prevent rust from forming and hindering movements involving brake shoe slots, anchor pins, and cam levers. Grease fittings are sometimes located on the brake shields for lubricating brake parts with a regular chassis lubricant. A semi-fluid or graphited grease lubricant similar to the kind used between spring leaves is often required. Anchor pins sometimes “freeze” and prevent the brake from working normally. Anchor pins should be thoroughly cleaned and lubricated with light oil and any excess oil should be wiped off. It is important to keep any lubricant from coming in contact with the braking surfaces (linings

and drums) so that their frictional properties are not affected. Brake parts requiring lubrication should be included in the regular chassis lubrication schedule for every 1,000 miles.

SECTION III

MECHANICAL SYSTEM

	Paragraph
Means of control.....	21
Hook-up	22
Front wheel control.....	23
Equalizers.....	24
Maintenance.....	25

21. Means of control.—*a.* The energy supplied by the operator's foot in pushing down on the brake pedal is transferred to the brake mechanism on the wheels by various means. A mechanical hook-up has been used since the earliest motor vehicles, but hydraulic pressure is most extensively used at the present time. Mechanically operated braking systems are practically obsolete. However, mechanical hook-ups are used for a portion of the braking system in many vehicles.

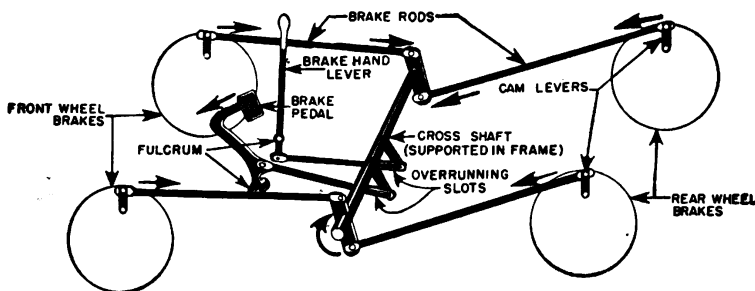


FIGURE 20.—Mechanical brake system with single cross shaft.

b. Power-operated brakes have come into widespread use on heavy-duty vehicles. The power medium acts as a booster to assist the operator in applying the brakes. Air, vacuum, and electric systems are employed to obtain power operation of the brakes. These systems are discussed in sections V, VI, and VII.

22. Hook-up.—*a. Cross shaft.*—(1) In a mechanical braking system the force applied to the pedal is transmitted to the brakes by means of rods and cables. The mechanical linkage may be arranged in various ways but its operation is essentially the same. In order to have all the wheel brakes applied uniformly, a cross shaft is provided near the center of the vehicle frame on which are mounted the levers connected to the rods and cables leading to the wheel brakes. The brake pedal is also connected to a lever on the cross shaft, as shown in figure 20.

(2) When the pedal is depressed, the cross shaft shown in figure 20 is turned so that the levers on the top of the shaft are turned backward and those on the bottom of the shaft forward. Thus by connecting the front brake rods to the levers on the top of the shaft and the rear brake rods to the levers on the bottom of the shaft, all the brake rods are pulled together and the four wheel brakes are applied at the same time.

(3) The usual practice in mechanical systems has been to link the handbrake to the footbrake so that both operate the same braking units. With such an arrangement the handbrake linkage incorporates an overrunning slot in the handbrake pull rod where it is connected to a lever on the cross shaft. This allows the pedal linkage to operate without interference from the hand lever. Both controls may be independently operated by also incorporating an overrunning slot in the footbrake linkage.

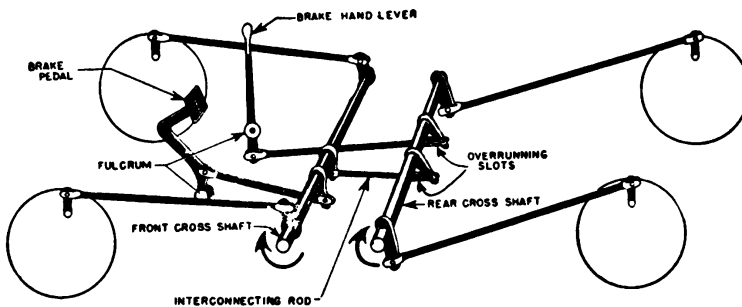


FIGURE 21.—Mechanical brake system with two cross shafts.

b. Two cross shafts.—In some mechanical brake arrangements two cross shafts are provided so that the handbrake is applied to the shoes on the rear wheels only (see fig. 21). The front and rear cross shafts are connected together by an interconnecting rod joined to a lever on each shaft. An overrunning slot must be provided on the interconnecting rod and the handbrake pull rod as shown in figure 21, if only the rear wheel brakes are to be applied by the brake handlever. Some braking systems incorporate additional shoes on the rear wheels for the handbrake, in which case the handbrake has its own cross shaft and hook-up and is in no way connected with the foot or service brakes.

23. Front wheel control.—The hook-up of the brake rods to the front wheels must be designed to allow the wheels to turn without locking in any position. If the front wheels lock, steering is destroyed.

a. *Universal joint*.—Attaching the brake rod to a camshaft with a small universal joint placed above the steering knuckle pivot so that the wheel pivots around it makes this possible. The brake rod does not move as the wheel is turned and it operates the brake camshaft or toggle lever regardless of the position of the wheels.

b. *Flexible steel cable*.—A more popular and satisfactory method employs a flexible steel cable connecting the end of the brake rod to

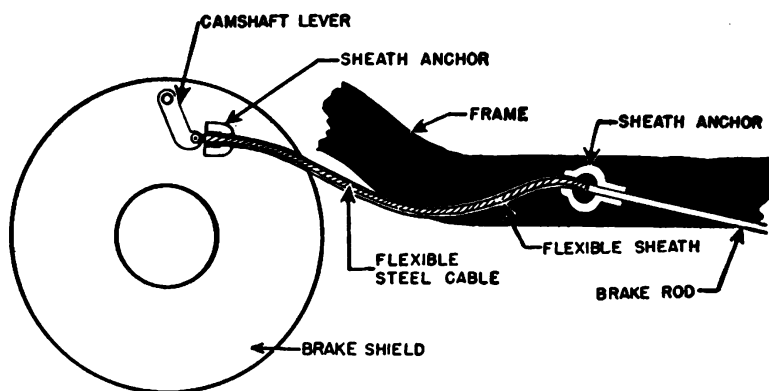


FIGURE 22.—Flexible steel cable.

the brake camshaft lever (see fig. 22). The cable is inclosed in a flexible sleeve or sheath, anchored rigidly at both ends to the frame and brake shield, which acts as a guide for the cable itself. Because of the flexibility of the cable and its sheath, motion of the wheel does not affect tension on the cable. When the brake rod is pulled,

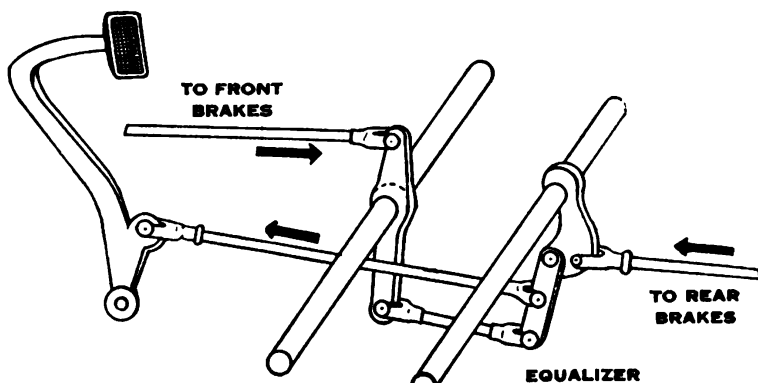


FIGURE 23.—Vertical equalizer.

the cable is pulled within its sheath and operates the camshaft lever. Flexible steel cables may also be used advantageously on the rear wheels because of the vibration of the wheels when traveling over the road.

24. *Equalizers*.—On some braking systems the pressure on the wheel brakes is evenly distributed by various types of equalizers.

AUTOMOTIVE BRAKES

Equalizers are designed to take up all the slack in the hook-up to each brake so that all brakes will be applied at the same time. This prevents the possibility of too much pressure being applied to any one brake which would lock that wheel and probably make the vehicle skid. Equalization is particularly important in modern high-speed vehicles because uneven braking may make the vehicle swerve. Control of the vehicle is very difficult when improperly adjusted brakes are applied at high speeds. One of the main reasons why the mechanical braking system is being supplanted is the difficulty of maintaining equal pressure on all brakes.

a. Vertical.—Figure 23 shows the most simple of vertical equalizers. The pedal rod is connected to the equalizer so that desired degree of braking effort is distributed between front and rear brakes. If any

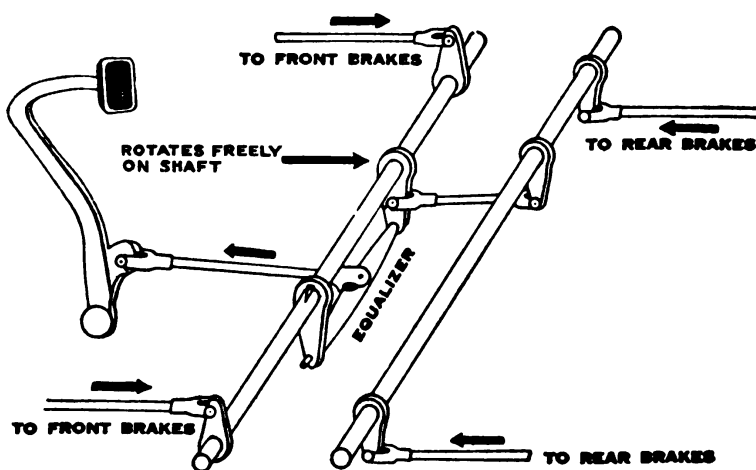


FIGURE 24.—Horizontal equalizer.

mechanical inequalities are encountered in the brake mechanism, the equalizer tends to overcome them since it can twist to take up uneven slack. Equalizers are not always of such simple design; however, the principle of operation is always the same.

b. Horizontal.—The effect produced by a horizontal equalizer, shown in figure 24, is the same as that produced by a vertical equalizer. The brake pedal is connected to the equalizer which controls two levers. One of these levers turns the front cross shaft while the other rotates freely on the front cross shaft and is connected by means of a short rod to another lever which turns the rear cross shaft. In this manner an equalization of pressure is obtained between front and rear brakes.

c. Self-equalizing.—By using a continuous cable from one brake to the other, the front or rear brakes are made self-equalizing. The

cable is run over a pulley or guide which is connected by linkage to the brake pedal. Moving the pulley by depressing the brake pedal tightens both ends of the cable to the same degree which equalizes the pressure.

25. Maintenance.—*a. Adjustments.*—Mechanical systems need frequent adjustment in order to obtain uniform application of shoes on all brakes. Wear of mechanical linkage and of braking surfaces creates slack in the brake hook-up. The hook-up to each brake has to be adjusted so that pressures are equalized. The brake mechanism or shoe assemblies or both are made adjustable to take up slack in the hook-up which results from wear. On a few vehicles adjustments are made on the brake control rods.

b. Lubrication.—(1) Periodic inspection of the braking system should be made to prevent binding and “freezing” of the parts and similar defects that result in faulty brake operation. Brake rods, levers, equalizers, etc., are exposed to dust, dirt, tar, water, etc., and consequently if neglected cause brake failures. All clevises, levers, and bearing surfaces of the handlever, pedal, rods, rockers, cross shafts, and of band or shoe assemblies in the braking system should be kept clean, loose, and lubricated. These parts should be cleaned with gasoline or kerosene, loosened with penetrating oil, and lubricated with oil or high grade, noncaking grease. Clevis pins or lever pivots should be lubricated with a grease if a lubrication fitting is provided, or with a few drops of oil each time a vehicle is lubricated during the monthly (1,000 miles) inspection. Brake cables covered by a flexible sheath normally should be removed, cleaned, and relubricated seasonally with a graphited grease to prevent sticking. Some flexible cable sheaths are equipped with fittings for pressure lubrication.

(2) Lubricants must be kept away from rubber parts as they deteriorate them. Working leather parts should be kept soft and pliable by saturating them with oil. Dry leather tends to crack and to cause undesirable squeaks.

(3) To keep the braking system on a motor vehicle in good condition, it is advisable to refer to the manufacturer's instructions which usually include necessary information on proper lubrication.

AUTOMOTIVE BRAKES

SECTION IV

HYDRAULIC SYSTEM

	Paragraph
Principle	26
Operation.....	27
Master cylinder.....	28
Wheel cylinder.....	29
Hill holder	30
Handbrake	31
Dual brake system.....	32
Fluid	33

26. Principle.—*a.* In hydraulic braking systems, the pressure applied at the brakepedal is transmitted to the brake mechanism by a liquid. To understand how pressure is transmitted by a hydraulic braking system, it is necessary to understand the fundamentals and

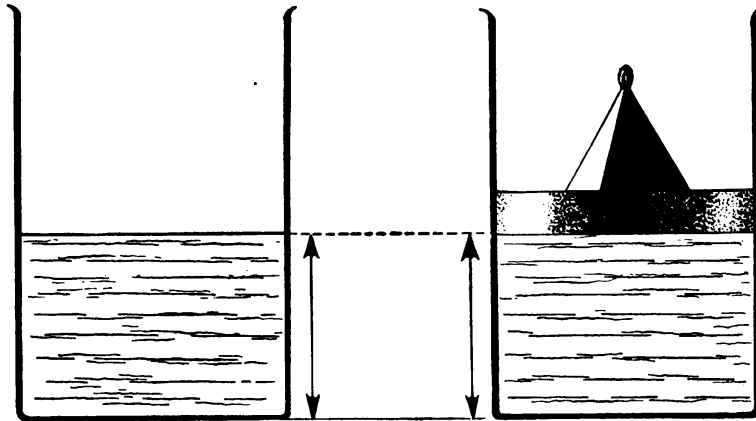


FIGURE 25.—Noncompressibility of liquids.

principles of hydraulics. Hydraulics is the study of liquids in motion or the pressure exerted by liquids conveyed in pipes or conduits.

b. One well-known hydraulic principle is that liquids cannot be compressed under ordinary pressures. The liquid in a jar, for instance, will maintain substantially the same volume when force is exerted upon it. This may be demonstrated by placing a weight on top of a piston fitted to a jar as shown in figure 25. The force of the weight does not change the level of the liquid, hence it does not diminish the volume or compress the liquid.

c. Another well-known hydraulic principle is that force exerted at any point upon a confined liquid is distributed equally through the liquid in all directions. That is, if a total force of 20 pounds, including piston and weight, is placed upon a jar of liquid and if the

piston on the jar has an area of 5 square inches, then the unit hydraulic pressure is increased by $\frac{20}{5} = 4$ pounds per square inch (see fig. 26). A gage inserted at any point in the jar will indicate an

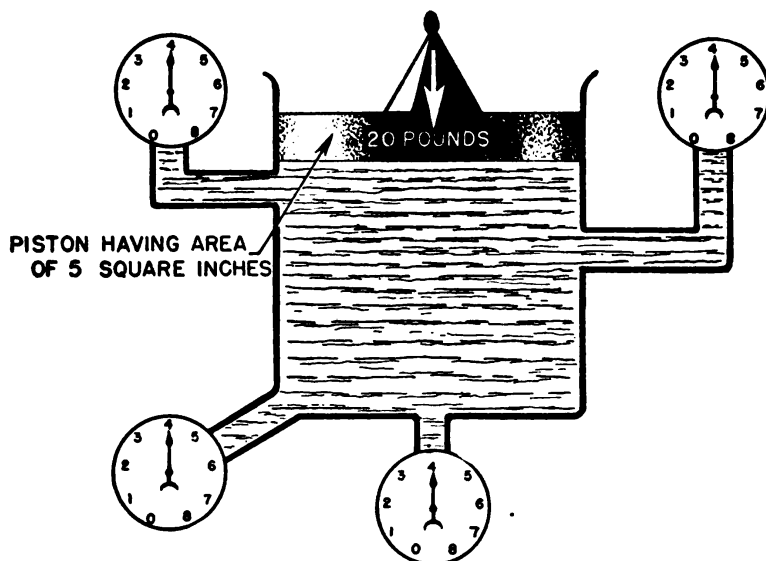


FIGURE 26.—Equal distribution of force upon confined liquid.

additional pressure of 4 pounds per square inch since the liquid transmits the pressure equally throughout the jar.

d. Use of these hydraulic principles may be illustrated by interconnecting two parts of the same diameter containing liquid, as

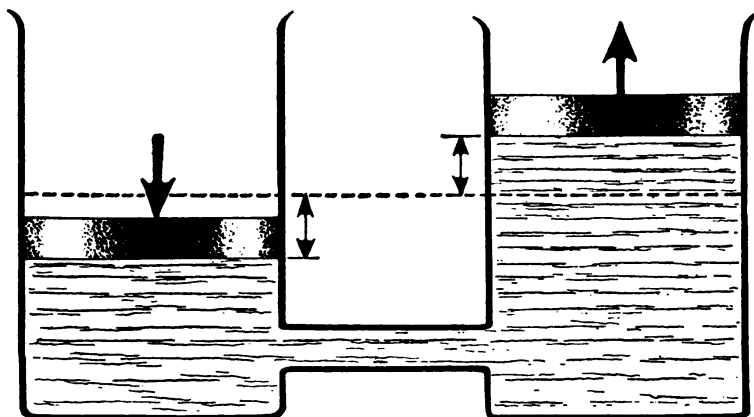


FIGURE 27.—Jars of same diameter interconnected.

shown in figure 27. If a force is exerted on a piston in one jar (the left jar in fig. 27), a piston placed in the other jar will receive the same amount of force due to the transmission of pressure by the liquid. When the areas of the two pistons are equal, moving one piston pro-

duces identical movement in the other piston since the liquid is not compressible and maintains the same volume.

e. By connecting one jar with another jar which has twice the diameter and therefore four times the area of the first jar (fig. 28),

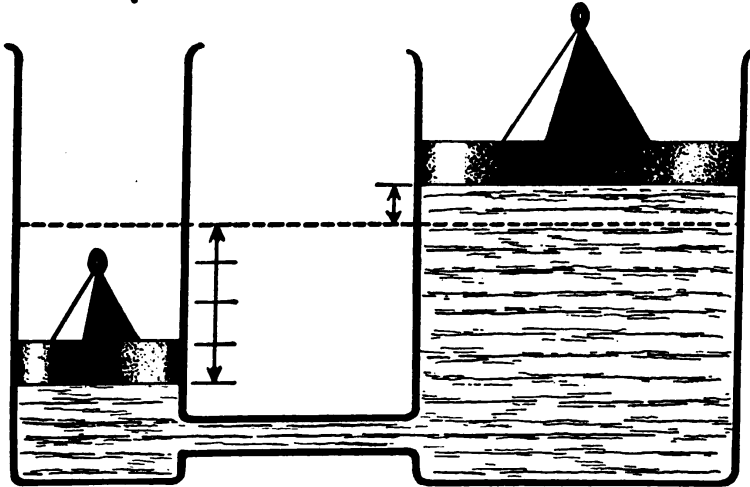


FIGURE 28.—Jars of different diameters interconnected.

the results are somewhat different, although the same basic facts apply. When a force is exerted on the piston in the small jar, the piston in the large jar will receive four times as much force, be-

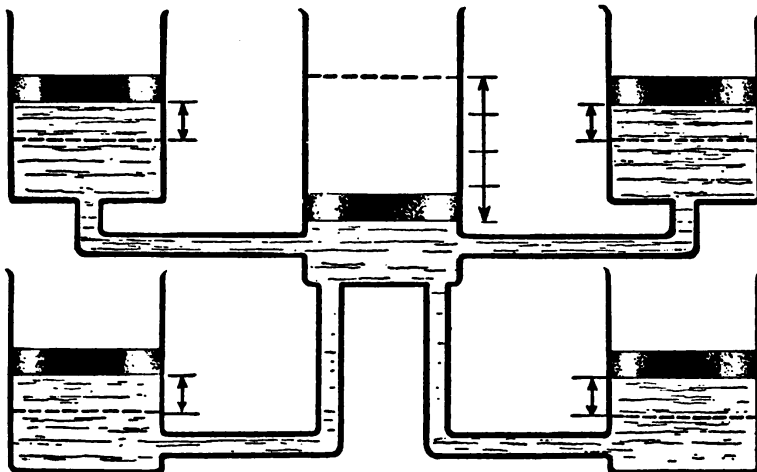


FIGURE 29.—Four jars connected to central jar.

cause the hydraulic pressure acts on four times the area. Since the liquid will always occupy the same volume, the large piston will move one-fourth as far as the small piston. Thus a mechanical advantage is obtained very similar to that obtained from a simple lever.

f. With four jars connected to a central jar, all of the same diameter, as shown in figure 29, an approximation of the action in four-wheel brakes is obtained. A force exerted on the piston in the central jar will be transmitted to each of the other jars so that the piston in each will receive an identical force but will move only one-fourth as far as the central piston.

g. If the four jars have a larger diameter than the central jar, then the total pressure on each of the four pistons is greater than that applied to the central one, and each of the four pistons moves less than one-fourth as far as the central piston. Hydraulic brake systems operate in such a manner.

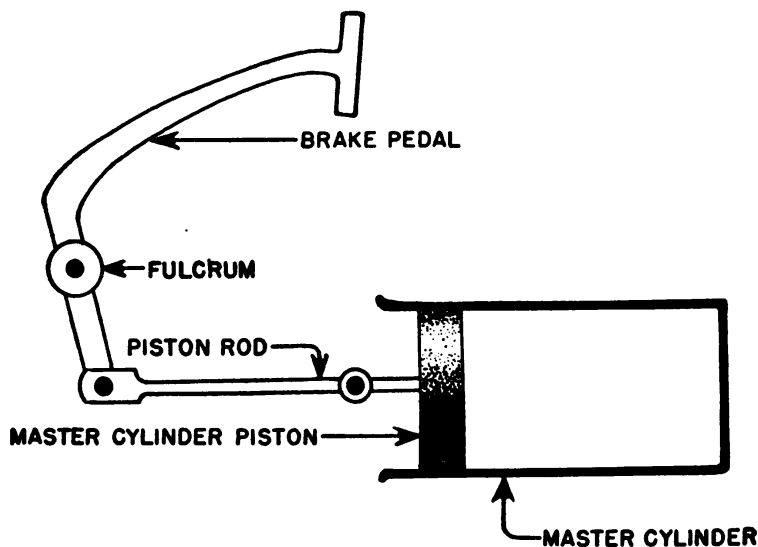


FIGURE 30.—Footpedal linkage to piston in master cylinder.

27. Operation.—*a.* In a hydraulic brake system, force is applied to a piston in a master cylinder that corresponds to the central jar in figure 29. The brakepedal operates the piston by a linkage as shown in figure 30. Each wheel brake is provided with a cylinder fitted with opposed pistons connected to the brake shoes.

b. The brakepedal when depressed moves the piston within the maser cylinder, thus forcing the brake liquid or fluid, as it is commonly called, from the master cylinder through tubing and flexible hose into the four wheel cylinders. A diagram of a hydraulic brake system is shown in figure 31.

c. The brake fluid enters each of the wheel cylinders between opposed pistons, making the pistons move the brake shoes outward against the brake drum. As pressure on the pedal is increased,

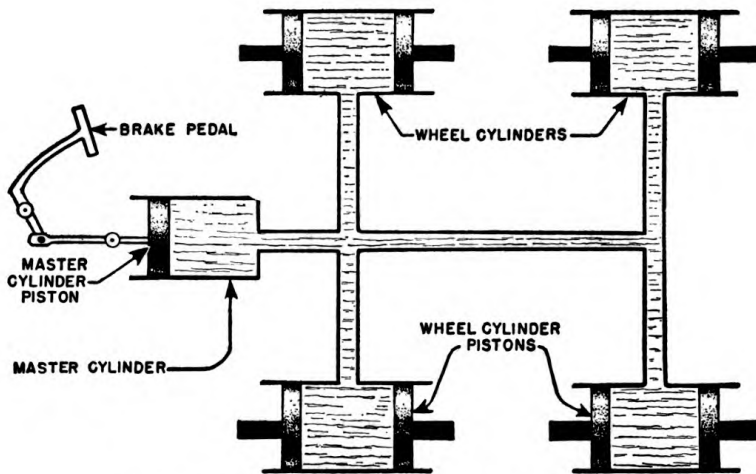


FIGURE 31.—Diagram of hydraulic brake system.

greater hydraulic pressure is built up within the wheel cylinders, and consequently greater force is exerted against the ends of the shoes.

d. When pressure on the pedal is released, the retracting springs on the brake shoes return the wheel cylinder pistons to their release position, thus forcing the brake fluid back through the flexible hose and tubing to the master cylinder.

28. Master cylinder.—*a. General.*—The master cylinder housing is an iron casting incorporating a large reservoir for the brake fluid (see fig. 32). The cylinder is sometimes a unit by itself, in which case a supply tank is provided to feed the fluid to the master cylinder by gravity. The reservoir carries sufficient reserve fluid to insure

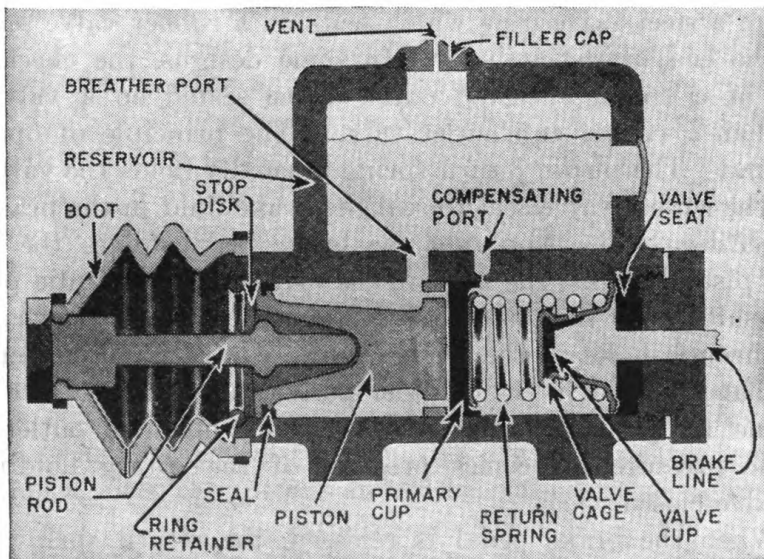


FIGURE 32.—Sectional view of master hydraulic brake cylinder.

proper operation of the braking system. It is filled through a hole at the top which is well sealed by a removable filler cap containing a vent. The cylinder is connected to the reservoir by two drilled ports, a large breather port and a small compensating port.

b. Piston.—The piston is a long, spoollike member with a rubber seal at the outer end and a rubber primary cup which acts against the brake liquid just ahead of the inner end. This primary cup is kept against the end of the piston by a return spring. A steel stop disk, held in the outer end of the cylinder by a ring retainer, acts as a piston stop. A rubber boot covers the piston end of the master cylinder to prevent dust and other foreign matter from entering it. This boot is vented to prevent air being compressed within it.

c. Check valve.—In the head of the master cylinder is a combination inlet and outlet check valve held in place by the piston return spring. The valve shown in figure 32 consists of a rubber valve cup

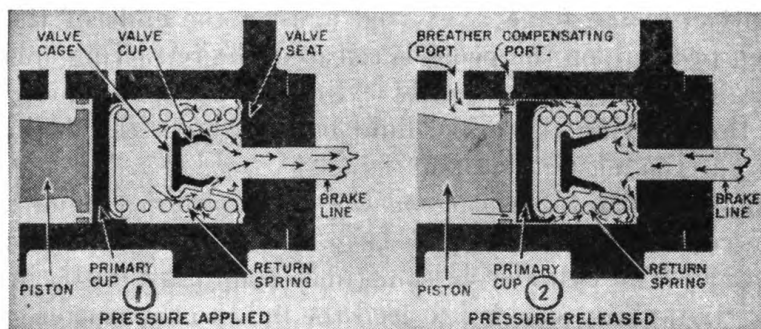


FIGURE 33.—Operation of master cylinder.

incased in a steel valve cage which seats on a rubber valve seat that fits in the end of the cylinder. In some designs, the check valve consists of a spring-operated outlet valve seated on a valve cage rather than a rubber cup outlet valve. The principle of operation is the same. The piston return spring normally holds the valve cage against the rubber valve seat to seal the brake fluid in the brake line.

d. Operation.—(1) Applying the brake pedal forces the master cylinder piston against the fluid in the cylinder. Hydraulic pressure which results when the piston passes the compensating port is transmitted through holes in the valve cage to contract the rubber valve cup so that the fluid in the cylinder passes through the valve to the brake line (see fig. 33①). With the spring-operated outlet valve, hydraulic pressure overcomes pressure of the spring holding the outlet valve closed.

(2) When the brake pedal is released, the return spring forces the piston and its primary cup back to released position. At the

same time the force of the retracting springs on the brake shoes increases the hydraulic pressure in the brake line to overcome the force of the return spring and push the valve away from its seat. Fluid from the lines flows around the valve back into the cylinder as shown in figure 33②. The piston and its primary cup return to the release position faster than the fluid returns through the line into the main cylinder. Because of this, a momentary vacuum is created in the main cylinder which draws additional fluid from the reservoir through the breather port, through drilled holes in the piston end and past the lip of the primary cup, as shown in figure 33②. Any excess is returned to the reservoir through the compensating port which is clear of the primary cup when the piston is against its stop. Thus a full cylinder of fluid is assured for every brake application. Some master cylinders have only one port (a compensating port) to accomplish action desired.

(3) When hydraulic pressure in the line drops to a value that is overbalanced by pressure of the master cylinder return spring, the valve settles on its seat. Thus the master cylinder return spring maintains a slight pressure in the brake line and wheel cylinders to prevent air entering the system.

(4) The check valve also acts as a seal to prevent fluid or air being drawn into the system through the bleeder hole during the bleeding operation. Fluid passed through the valve on the pressure stroke can return into the master cylinder only by raising the entire valve from its seat. Since there is no pressure in the brake line when the bleeder hole is opened, the valve is held in place by the piston return spring.

29. Wheel cylinder.—*a. Description.*—The wheel cylinder is the unit which changes the applied hydraulic pressure into mechanical force at the wheel braking surfaces. The wheel cylinder housing, made from a casting, is rigidly mounted on the brake shield. Within the cylinder (fig. 34) are two pistons which are moved in opposite directions by hydraulic pressure and push the brake shoes against the drum. The stems of the opposed pistons are connected to the ends of the brake shoes. Sometimes the brake shoe ends are made to fit directly against the pistons, as shown in figure 35. A rubber piston cup fits tightly in the cylinder bore against each piston and acts as a seal to prevent escape of brake liquid from the system. A light spring is placed between the piston cups to keep them in position against the pistons and to keep the pistons against their stems. Open ends of the cylinder are fitted with rubber boots to protect the cylinder from foreign substances. Brake fluid enters

the cylinder from the brake line connection between the opposed pistons. At the top of the cylinder between the pistons is a bleeder hole through which air is released when system is filled with brake fluid.

b. Adjustment.—Sometimes an adjustment is provided on the wheel cylinder to bring the brake shoes closer to the drum when braking surfaces are worn. Such an adjustment is shown on the wheel cylinder in figure 19. By turning an adjusting cap on the wheel cylinder end cover the threaded stem will move the brake shoe closer to the drum. When the wheel cylinder has no adjustment, the brake shoes are usually brought closer to the drum by means of adjusting cams on the brake shield that push against the shoes.

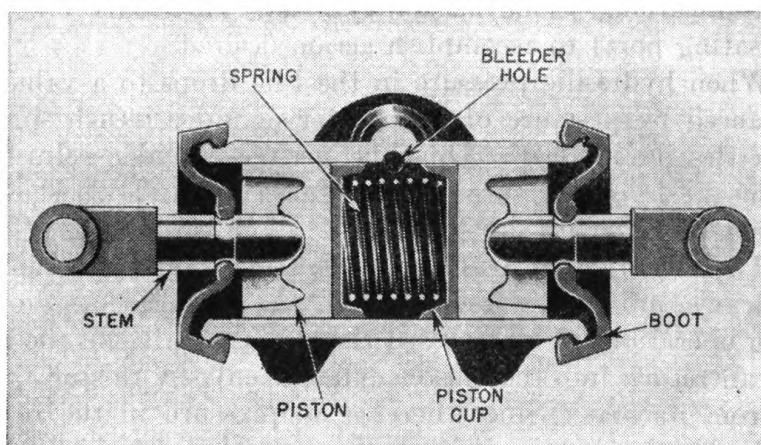


FIGURE 34.—Sectional view of wheel cylinder.

c. Stepped cylinders.—Ordinarily the lining on the front shoe of each wheel brake wears at a faster rate than lining on the rear shoe due to self-energizing action. Less lining is usually used on the rear shoes to equalize wear. A better arrangement, which equalizes wear without reducing the effective lining area, is use of a larger piston at the rear shoe. The rear shoe then receives more pressure than the front shoe to compensate for the self-energizing action on the front shoe. This requires a stepped wheel cylinder with two bore sizes, as shown in figure 35.

d. Single piston cylinders.—(1) In order to have both shoes on the front brakes independently self-energizing in the forward direction, wheel brakes with two single piston cylinders have been introduced. The two cylinders are mounted on opposite sides of the brake shield, the cylinder housings being supported on the anchor pins as shown in figure 36.

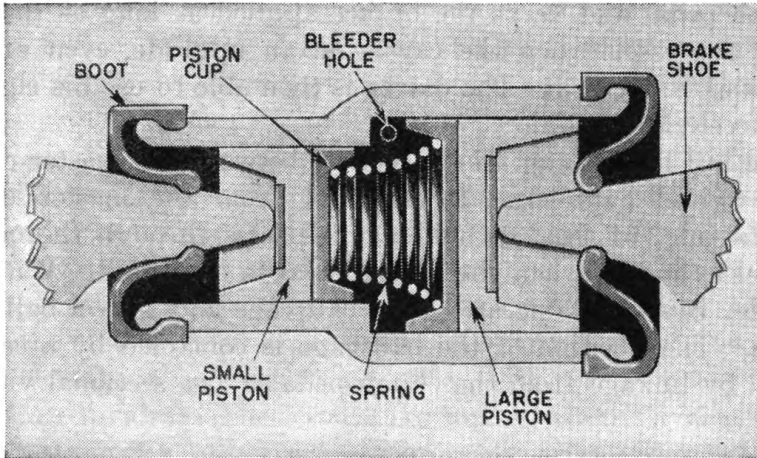


FIGURE 35.—Sectional view of stepped wheel cylinder.

(2) Such an arrangement is useful with the system of weight distribution used on many modern vehicles which requires about 60 percent of braking effort on front wheels and 40 percent on rear wheels. With front wheels having two single-piston cylinders and rear wheels having the conventional single cylinder with two opposed pistons, six shoes are self-energizing in forward direction and two in backward direction.

30. Hill holder.—*a.* The hill holder provides greater ease of vehicular control on hills and in traffic. The device is connected to

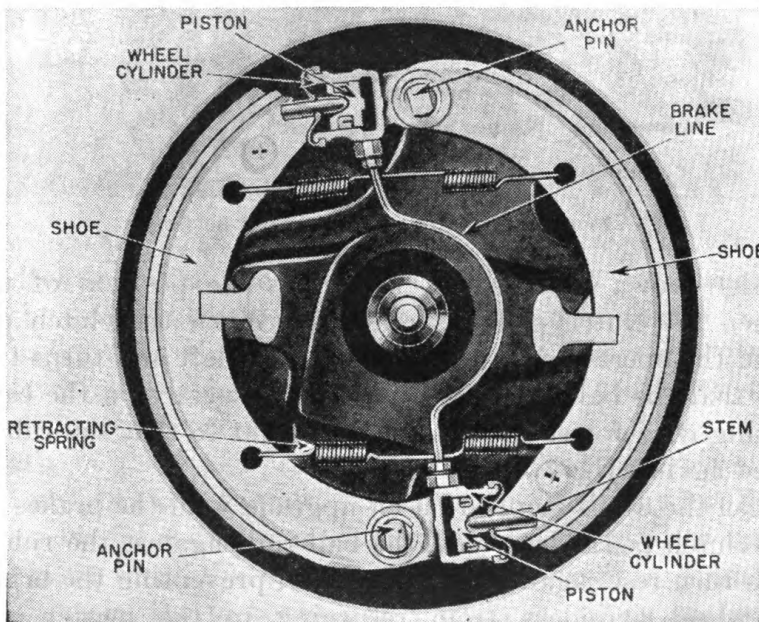


FIGURE 36.—Two single piston cylinder mounting.

the clutch pedal and keeps the brakes applied as long as the clutch pedal is depressed when the car is on an upgrade, even after the brake pedal is released. The driver is then able to use his right foot for the accelerator pedal.

b. The hill holder (fig. 37) is located between the master cylinder and the wheel cylinders. Brake fluid from the master cylinder enters the inlet of the hill holder and passes through the outlet to the wheel cylinders when the brake pedal is depressed. Within the hill holder is a valve operated by a ball cage and a steel ball within the cage. The position of the ball cage is controlled by a camshaft operated by linkage from the clutch pedal. The sectional view of a

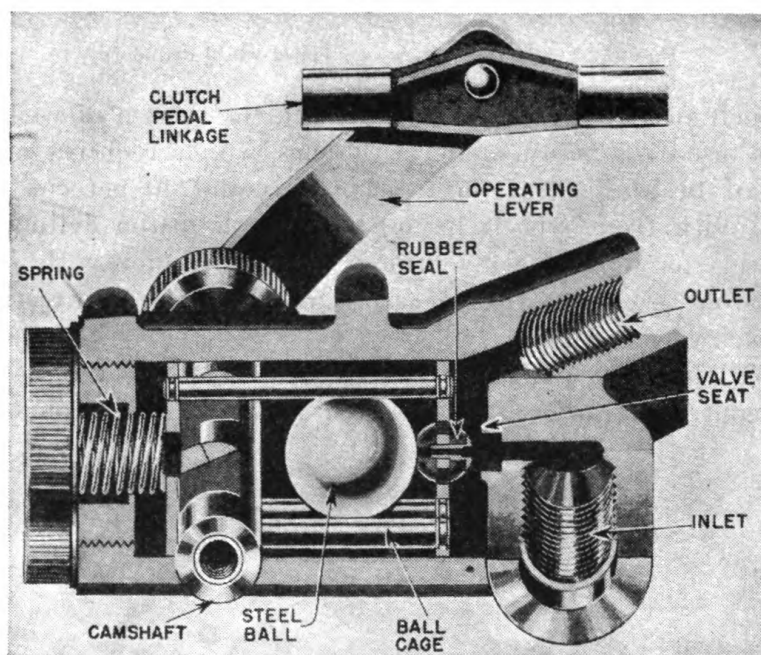


FIGURE 37.—Sectional view of hill holder.

hill holder shown in figure 37 illustrates the position of the ball cage when the clutch pedal is released. When the clutch pedal is depressed the operating lever is pulled to the left and turns the camshaft so that the ball cage fits into the flat surface on the camshaft. The spring then forces the ball cage to right so that the rubber seal is pressed against the valve seat.

c. When the car is stopped on an upgrade with the brakes applied and the clutch pedal depressed, the ball rolls against the rubber seal which in turn rests against the valve seat, preventing the brake fluid in the wheel cylinders from returning to the master cylinder. Pressure is therefore maintained in the wheel cylinder to keep brakes

applied. When clutch pedal is released, the camshaft is rotated and lifts the ball cage away from the valve seat, allowing brake fluid to pass through the valve to the master cylinder, thus releasing the brakes.

d. When the vehicle is on a downgrade, the ball rolls away from the rubber seal rendering the valve inoperative regardless of the clutch pedal position. The hill holder does not affect ordinary use of the brakes for when the brakes are applied, pressure of the fluid from the master cylinder forces the ball cage back against the spring even if the clutch pedal is depressed, allowing fluid to flow through the outlet to the wheel cylinders.

31. Handbrake.—The handbrake in a hydraulic system operates mechanically either on a transmission brake or on the brake shoes of

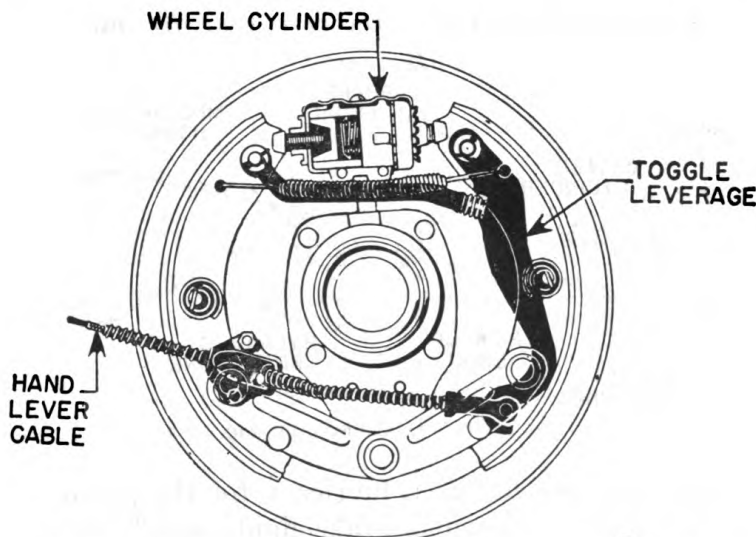


FIGURE 38.—Handbrake linkage on brake hydraulically operated.

the rear wheels. The transmission brake, entirely independent of the hydraulic system, is of the type described in paragraph 17. When the handbrake operates on the wheels, it is usually linked to the same shoes that are operated by the hydraulic pistons. A toggle leverage, as shown in figure 38, is usually used to apply the shoes. With this arrangement the shoes are applied either hydraulically by the brake pedal or mechanically by the hand lever.

32. Dual brake system.—In addition to the hydraulic system some cars are fitted with a mechanical device designed to act on rear wheel brakes after the brake pedal has traveled a predetermined distance toward the toeboard. In normal operation braking action is wholly one of hydraulic force. A diagram of this design is shown

in figure 39. While the actual lay-out of the braking mechanism is somewhat more complicated than this, figure 39 illustrates how the mechanical hook-up works in connection with the hydraulic system. The hydraulic fluid flows at all times to both front and rear brakes from the master cylinder. The pick-up link allows the brake pedal to travel a certain distance before the mechanical hook-up acts. With correct quantity of fluid in the lines and brakes properly set, the mechanical hook-up is inactive. If the hydraulic system fails for any reason, the mechanical linkage acts as a safeguard. This mechanical hook-up serves a further use since it may be connected to the handbrake lever for parking.

33. Fluid.—The liquid used for hydraulic braking is usually termed "brake fluid." It is composed chiefly of equal parts of alcohol and castor oil. This combination gives a liquid that does not freeze or boil at the temperatures encountered in year-around operation of

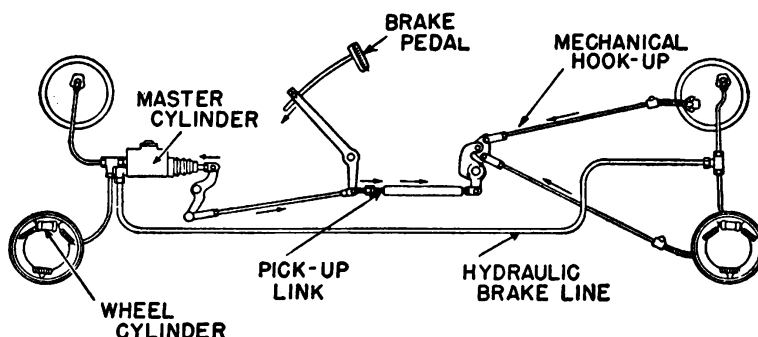


FIGURE 39.—Dual brake system.

motor vehicles. It also acts as a lubricant for the pistons and preserves the rubber cups. Various brake fluids supplied by different manufacturers should not be mixed. Brake fluid should never be added to a brake system containing any trace of any other kind of liquid since the mixture might form a gummy sediment which will obstruct the ports and destroy the rubber cups. Gas, which seriously affects the function of brake fluid, is sometimes produced by mixing certain brands of brake fluid. Shockabsorber fluid and other liquids containing mineral oil must never be used as a brake fluid since mineral oil attacks rubber.

a. Brake lines.—The brake lines which transmit the fluid from the master cylinder to the wheel cylinders are made of tubing and flexible hose. Connections must be tight so that no liquid can escape from the system. Tubing and flexible hose must be able to withstand hydraulic pressure developed when the brakes are fully applied. Tubing, usually about $\frac{1}{4}$ inch in diameter, is made of copper or steel.

Both ends of all tubing are flared at an angle so the tube may be tightly clamped to the fittings. Flexible hose must carry the brake liquid to the wheels because of the movement between frame and wheels.

b. Bleeding.—(1) Air enters into the hydraulic brake lines and wheel cylinders if fluid level is too low, if fluid leaks out, or if any part of the system is disconnected. Since air seriously affects braking efficiency, it is necessary to bleed the system to remove any air. The hydraulic system should be bled whenever brakes are adjusted. All wheel cylinders must be separately bled to make sure that all air is removed.

(2) The bleeder valve, located above the brake line connection to the wheel cylinder, consists of a fitting that plugs the bleeder hole in the wheel cylinder. To bleed the system the screw which is threaded into this fitting is replaced by a hose connection. The free end of the hose should be submerged in a clean glass container to collect the brake fluid and prevent it getting on the brake drum. The bleeder valve is opened by unscrewing the bleeder hole fitting one-half to three-quarters of a turn.

(3) The system is bled by using a pressure tank or by pumping the brake pedal. The pressure tank, which contains brake fluid under pressure, is connected to the reservoir filler hole. When the bleeder valve is opened, pressure from the tank forces brake fluid through the check valve into the brake lines. When fluid comes out in a solid stream without air bubbles from end of hose in glass container, the bleeder valve is closed tightly.

(4) Before bleeding the system by pumping the brake pedal the reservoir should be filled. The brake pedal should be pressed slowly through half or more of its limit of travel and allowed to return to its released position, after which it may be depressed again until the fluid comes out of the bleeder hose in a solid stream without air bubbles. When the bleeder valve is open there is no pressure within the system so the master piston return spring holds the check valve closed on the return stroke of the brake pedal. This creates a vacuum within the cylinder which collapses the lip of the piston cup and allows fluid to enter from the reservoir, thus refilling the master cylinder after each stroke of the brake pedal. Since 6 to 10 half strokes of the brake pedal will empty the reservoir, it is advisable to refill the reservoir after bleeding each wheel cylinder.

(5) After each wheel cylinder is bled and its bleeder valve closed, its bleeder screw should be replaced before the next cylinder is bled. When all the cylinders have been bled the reservoir should be filled to within $\frac{1}{2}$ inch from the top.

SECTION V

AIR SYSTEM

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34. Power system.—*a.* The increase in motor vehicles' speeds and capacities made necessary the development of a method of brake operation more effective in application and less strenuous for a driver than systems operated entirely by physical effort. The direct physical force of a driver's foot is limited, and the advantage of leverage is limited by the distance a driver's foot can reasonably travel. Under these conditions it is impossible for a driver to apply sufficient braking action to control properly a heavily loaded vehicle at high speed. Power systems were developed to assist the force of a driver's foot in applying brakes.

b. One of the most outstanding power systems of brake application for motor vehicles is the air-brake system. The fundamental characteristic of the air-brake system is that the brakes, although controlled by the driver, are applied by pressure of compressed air. Compressed air provides sufficient braking force to control even the heaviest vehicles.

35. Compressed-air principle.—*a.* Unlike liquids, gases are easily compressed. If a gas such as air is confined and a force applied to it, it is compressed and has less volume. Such a force may be exerted by placing a weight on a piston that fits into a container as shown in figure 40. The air that originally filled the entire container as shown in figure 40① is pressed into only a portion of the container due to the force of the weight upon it as shown in figure 40②. The pressure of the compressed air due to the force exerted

upon it by the weight will be equally distributed in all directions just as it is in a liquid.

b. Compressed air may be conveniently stored under pressure and made available for the power application of brakes.

36. Essential Action.—An air pump or compressor driven by the engine is used to compress air and force it into a reservoir where it is stored under pressure and made available for operating the brakes. Air under pressure in the reservoir is released to the brake lines by an air valve operated by the brake pedal. This released air goes to brake chambers located close to the wheel brakes which contain a flexible diaphragm. Against this diaphragm is a plate which is directly connected by linkage to the mechanism on the wheel brakes. The force of the compressed air admitted to the chamber causes

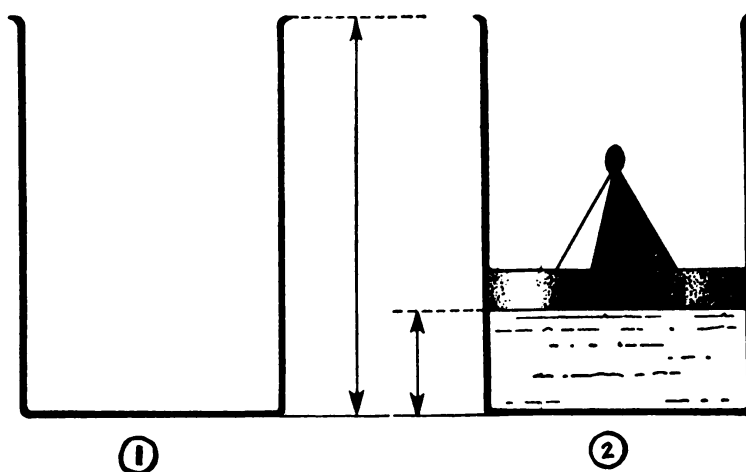


FIGURE 40.—Compressibility of gas.

the diaphragm to move the plate and operate the brake shoes through the linkage. Considerable force is available for braking since operating air pressure may be as high as 100 pounds per square inch. All brakes on a vehicle, and on a trailer when one is used, are operated together by means of special regulating valves.

37. Fundamental Units.—a. A diagram of a typical air brake system used on a motor vehicle is shown in figure 41. The fundamental units and their functions are—

- (1) Compressor, driven directly from engine crankshaft or from one of auxiliary shafts to furnish compressed air for brake operation.
- (2) Governor to limit pressure produced by compressor within a predetermined range.
- (3) Reservoir to receive air from compressor and store it for use in the braking system. Two reservoirs are usually used.

(4) Brake valve to control brake operation by directing flow of air from reservoir to brake chambers when brakes are applied, and from brake chambers to atmosphere when brakes are released.

(5) Brake chambers, one for each wheel, to convert pressure of compressed air into mechanical force for applying brakes.

(6) Quick release valve to speed up exhaust of brake chambers not close to brake valve so all the brakes may be quickly released.

(7) Relay valve used on trailers and trucks with long wheel bases to speed operation of rear wheel brakes. On trucks with short

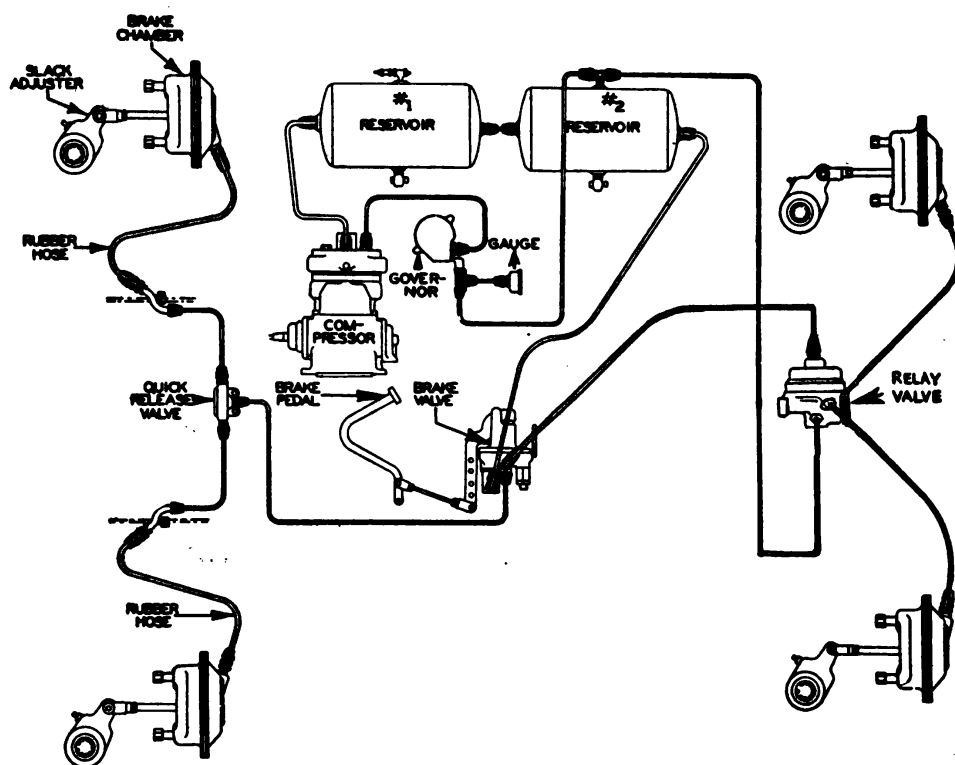


FIGURE 41.—Diagram of typical air brake system.

wheel bases the shorter length of brake lines permits rapid rear brake action without aid of a relay valve.

b. Construction and operation of these fundamental units are individually discussed below in the order listed. Other devices shown in figure 41 are not basically important in the operation of the system. Function of these devices is discussed with their associated units or in paragraph 48.

38. Compressor.—*a. Description.*—(1) The compressor is a reciprocating pump driven directly from the engine crankshaft or from one of the auxiliary shafts. It is very similar in construction to an

internal combustion engine. Two-cylinder compressors are usually used with a capacity of 3 to 8 cubic feet of free air per minute when driven at 1,250 revolutions per minute. A piston is moved up and down in each cylinder by a driven compressor crankshaft. The air is compressed by the pistons forcing air out of the cylinder bores into a reservoir, gradually increasing the pressure of the air in the reservoir until it is high enough to operate the air brake system.

(2) The compressor for air brake systems is single-acting (air is compressed on one side only of piston). Cylinders are either vertical or horizontal, usually being vertical when driven from an auxiliary shaft of the engine and horizontal when driven directly from the

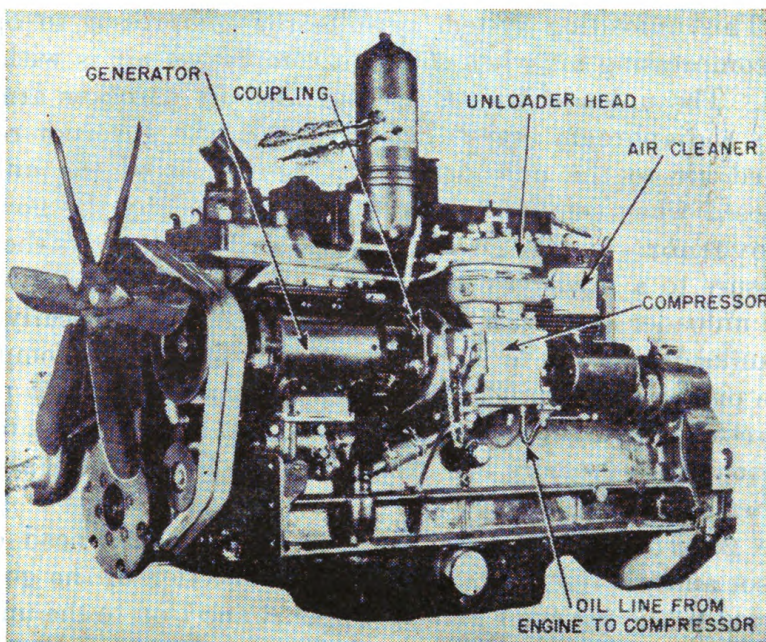


FIGURE 42.—Vertical compressor mounted on engine.

engine crankshaft. Compressors are lubricated either through a self-contained lubricating system or from the engine lubricating system. Mounting of a vertical compressor on an engine is shown in figure 42. The compressor illustrated is driven from the generator shaft through a coupling.

b. Air strainer.—If dust and dirt are permitted to enter the compressor with the air, proper lubrication becomes impossible because the dirt mixes with oil to form a very effective grinding compound which increases wear on the cylinders, pistons, piston rings, and valves. An air strainer is provided to allow only clean air to enter the compressor. This consists of an aluminum casing with a compact

layer of pulled curled hair held between two perforated brass plates through which air entering the compressor passes. Strainers are furnished in different styles, depending on type of compressor and installation clearances.

a. Unloader head.—Compressor cylinder heads have discharge valves and unloader valves. The discharge valves are spring-loaded and operate only when the compressor is supplying air under pressure to the reservoir. Since the compressor operates continuously when the engine is running, some means has to be used to prevent it from building up excessive pressure in the reservoir. The purpose of the unloader valves is to stop compression of air in the compressor by allowing air to pass from cylinder to cylinder through an unloader cavity. This unloading system permits the compressor to operate without compressing air when sufficient compressed air is within the reservoir. The unloader valves are operated by a rocker arm controlled by a diaphragm that is deflected when the governor releases compressed air to the unloader head. Springs hold the unloader valves closed when compressed air is not supplied by the governor.

39. Governor.—*a.* The governor is a device which limits the reservoir pressure to a predetermined range. It operates in conjunction with the unloader system of the compressor by automatically opening the unloader valves to stop compression within the compressor when the pressure has built up to the upper limit (about 105 pounds per square inch) and automatically closes the unloader valves to start compression when pressure has dropped to the lower limit (about 85 pounds per square inch).

b. The governor is connected between the unloader head of the compressor and the reservoir. The lower connection of the governor is connected to the reservoir and the upper connection to the unloader head of the compressor, as shown in figure 43. The operation of the governor depends on a flexible tube like that used in a pressure gage. The bottom end of the tube opens into the reservoir connection and the top end, which is sealed, supports a bracket and operates an upper and a lower valve through a valve stem.

c. The sectional view of a governor in figure 43 shows its operation when air is being compressed. The reservoir pressure is below the upper limit and the tension exerted by the tube through the bracket and valve stem holds the lower valve seated, preventing escape of air from the reservoir. The unloader connection is open to the atmosphere through the exhaust port in the valve guide so that the unloader valves in the compressor are seated, permitting normal compression past the discharge valves to the reservoir.

d. When the pressure in the reservoir reaches the upper limit the force of the air pressure deflects the flexible tube, overcoming its tension so that the lower valve with the aid of a spring unseats and the upper valve seats. The unloader head is then closed to the atmosphere and opened through the lower valve to the pressure in the reservoir. This pressure forces the unloading valves to open and stops compression in the compressor.

e. When the reservoir pressure drops to the lower limit, the governor tube returns to its original position, forcing the lower valve to its seat, cutting off the unloader head from the reservoir pressure,

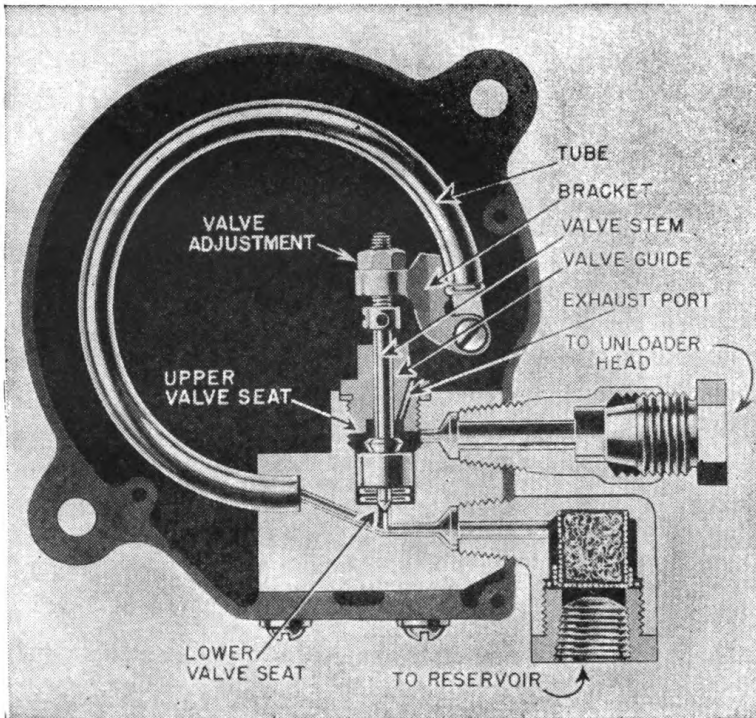


FIGURE 43.—Sectional view of governor for air brake system.

and unseating the upper valve, thereby opening the unloader head to the atmosphere. Compression is then resumed to build up reservoir pressure.

40. Reservoir.—*a.* Reservoirs, made of steel, are designed with a large factor of safety. Two coats of baked enamel, inside and out, prevent rust and corrosion.

b. Two interconnected reservoirs are usually used, as shown in figure 41, except with smaller vehicles. Because most of the condensation occurs in No. 1 reservoir into which the compressor forces fresh air, this reservoir is known as a wet reservoir and the No. 2

reservoir as a dry reservoir. A drain cock is provided on the bottom of each reservoir to permit draining any condensed water that collects there. Each reservoir should be drained daily to reduce possibility of trouble caused by condensation. Reservoirs should be mounted lower than any other unit of the air brake system so that any condensed water will drain back to the reservoir. Whenever possible, the dry reservoir should be mounted higher than the wet reservoir so that all the condensed water drains to the wet reservoir and leaves the No. 2 reservoir with dry air for the system. This

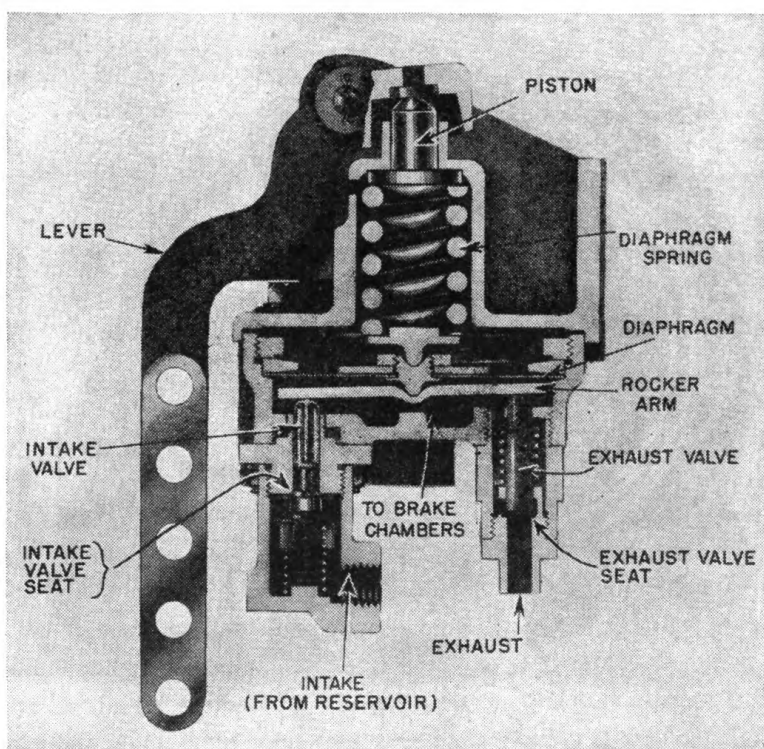


FIGURE 44.—Sectional view of air brake valve.

reduces the possibility of moisture gathering on any of the operating units of the system where it might freeze or cause corrosion.

c. A safety valve is mounted on top of a reservoir to relieve excessive pressures. If two reservoirs are used the safety valve is mounted on the No. 1 reservoir. When pressure in the reservoir exceeds 150 pounds per square inch, the safety valve allows excess air to escape.

41. Brake valve.—*a.* The brake pedal operates the brake valve lever through suitable linkage. This lever controls the operation of the brake valve by acting on a metal diaphragm through a piston and a diaphragm spring (see fig. 44). Below the diaphragm is a cavity connected to the brake chambers and containing a rocker arm

that operates an intake valve leading to the reservoir, and an exhaust valve leading to the atmosphere.

b. With the brake valve lever in the release position the exhaust valve is held open and the intake valve held closed by springs, as shown in figure 44. Depressing the brake pedal pulls the brake valve lever which pushes the diaphragm spring down and depresses the diaphragm. A rocker arm pivoted on the center of the diaphragm is forced downward with the diaphragm. It completely closes the exhaust valve and then opens the inlet valve to admit air from the reservoir to the brake chambers. When air pressure below the diaphragm is enough to lift the diaphragm and compress the diaphragm spring, the intake valve is closed by its spring. The braking effort is then balanced by the diaphragm spring pressure, which in turn is controlled by the position of the brake valve lever. A further movement of the lever compresses the diaphragm spring still more and the balance is established at a higher pressure; a movement of the lever toward the release position permits the diaphragm to lift which opens the exhaust valve and releases enough air from beneath the diaphragm to balance the braking effort at a lower pressure. When the lever is released, the exhaust valve stays open so that all the air in the brake chambers is exhausted to the atmosphere.

42. Brake chambers.—*a.* The brake chamber is formed by two dished metal plates separated by a rubber and fabric diaphragm. Rear wheel brake chambers are mounted on the rear axle and front wheel chambers are mounted on the front wheel brake shield. A spring on one side of the diaphragm holds a push rod plate against the diaphragm, as shown in figure 45. The portion of the brake chamber on the other side of the diaphragm is connected to the service line leading to the brake valve. The dish plate which contains the service line connection is called the pressure dish plate.

b. When air is released through the service line by operating the brake valve, the pressure exerted on the diaphragm deflects it against the spring pressure and forces the push rod to move and operate the brake shoes as shown in figure 46.

c. The brake chamber push rod is attached to the slack adjuster arm. A worm gear that rotates with the arm is splined to the cam shaft that operates the brake mechanism. Therefore when brakes are applied, the brake chamber push rod forces the entire slack adjuster as a unit to rotate the camshaft. The slack adjuster (fig. 47) provides a quick and easy method of adjusting brakes. Adjustment is made by adjusting nut which rotates the worm and worm gear to take up the slack in the camshaft.

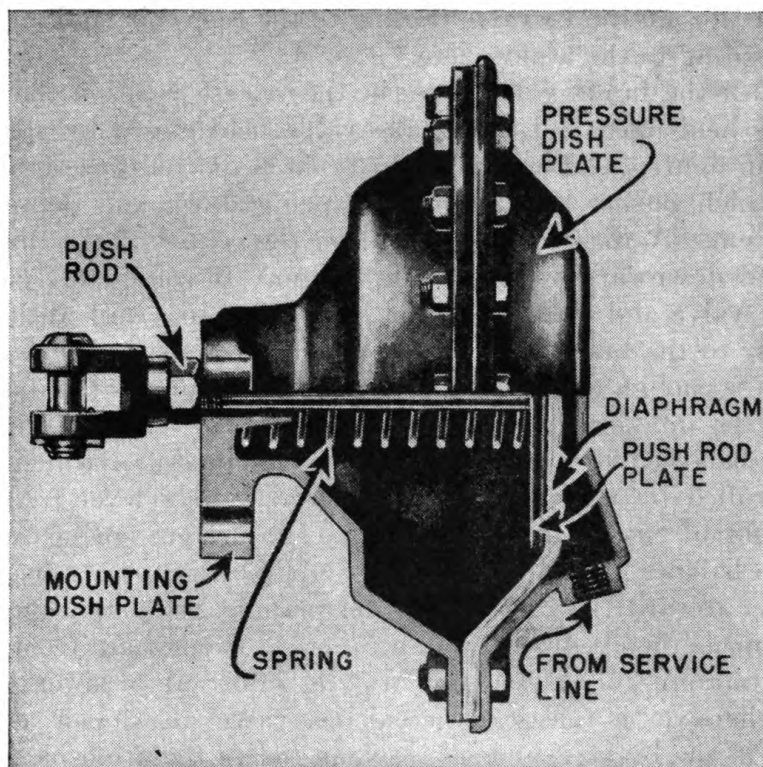


FIGURE 45.—Sectional view of air brake chamber.

43. Quick release valve.—*a.* The quick release valve is installed close to the brake chambers that are too far from the brake valve to be quickly released through it. When the brake valve is operated, it sends air into the intake of the quick release valve (fig. 48), pushing diaphragm and attached valve downward onto its seat. When air pressure overcomes the diaphragm spring, the air passes around the diaphragm to the two side connections, each of which leads to a brake chamber. The diaphragm spring seats the diaphragm when the pres-

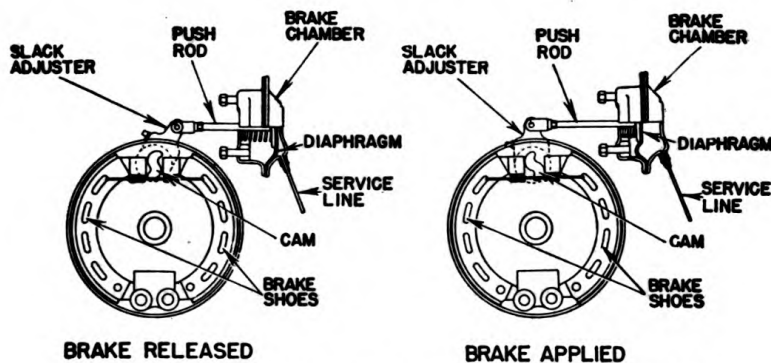


FIGURE 46.—Operation of brake shoes from brake chamber.

sure in the brake chambers approaches that of the brake valve. The quick release valve then holds the pressure in the brake chamber until the brake valve is again operated.

b. When the brake valve is in release position, pressure above the diaphragm is reduced so that pressure under the diaphragm from the brake chambers deflects the diaphragm upward. This lifts the valve

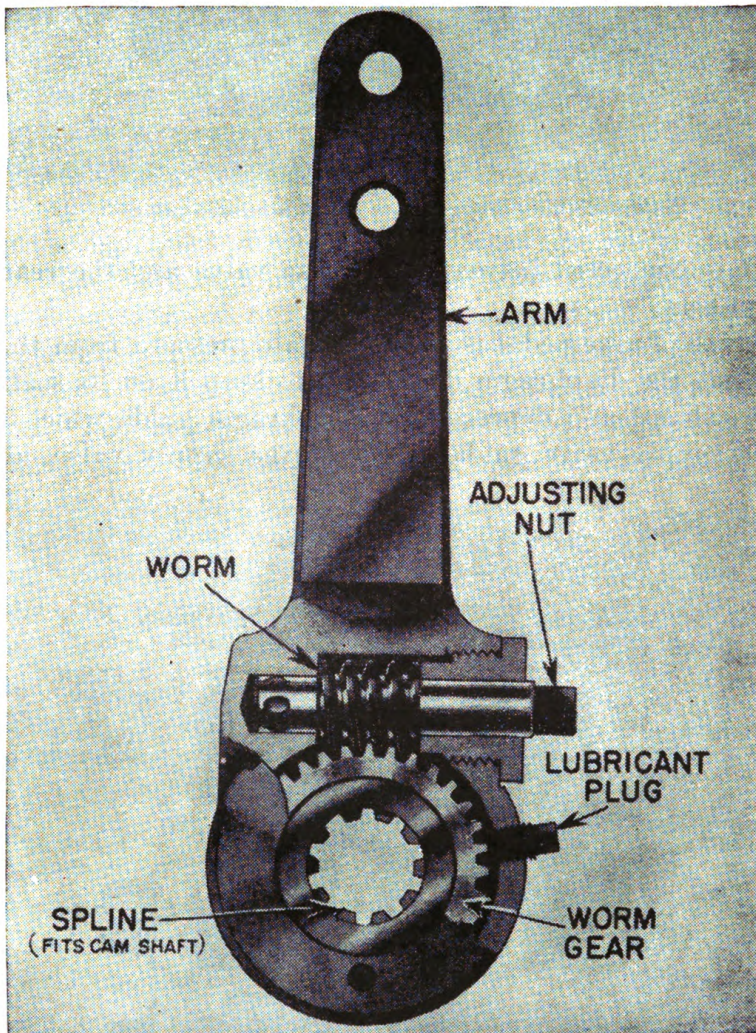


FIGURE 47.—Sectional view of slack adjuster.

from its seat, which opens the exhaust so that air in the brake chambers escapes to the atmosphere without having to go through the brake valve.

44. Relay valve.—*a.* The relay valve (fig. 49) is used on trailers and long wheel base and six-wheel trucks to speed application and release of the rear wheel brakes by relaying the action of the brake

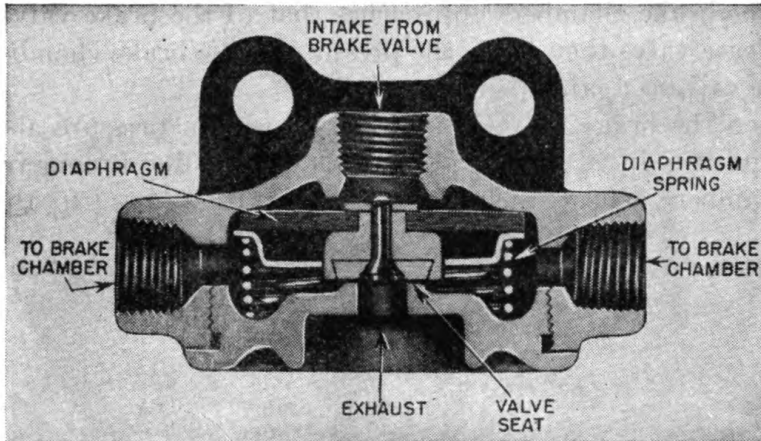


FIGURE 48.—Sectional view of quick release valve.

valve. It is connected between the brake valve and the rear wheel brake chambers.

6. When the brake pedal is depressed, air pressure from the brake valve deflects the diaphragm downward to keep it on its seat. This closes the exhaust and depresses the diaphragm guide which in turn forces the supply valve guide to unseat the supply valve, allowing

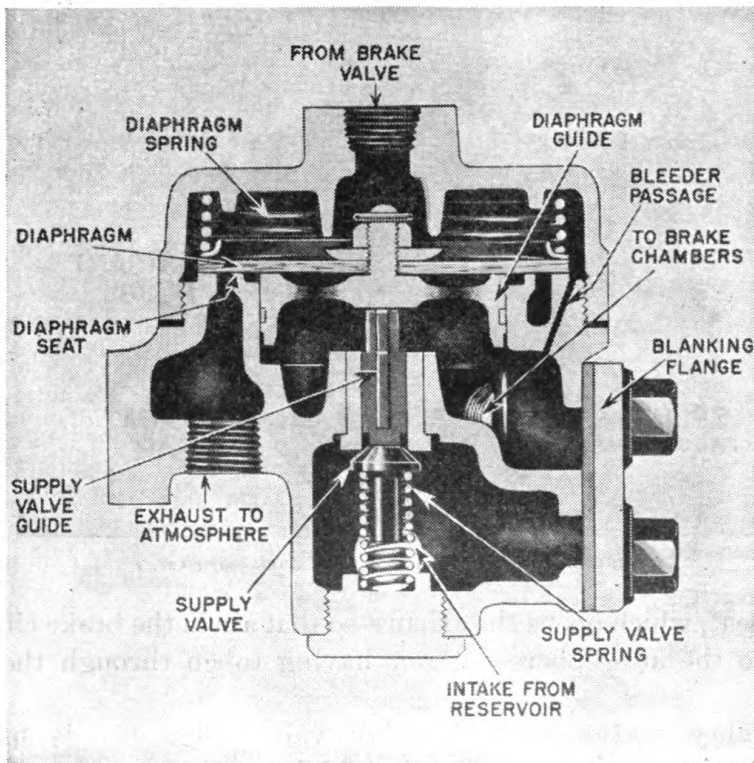


FIGURE 49.—Sectional view of relay valve (air system).

reservoir pressure to pass through the supply valve to the brake chambers. When pressure in the brake chamber equals pressure on top of the diaphragm from the brake valve, the supply valve spring forces the supply valve up to its seat to close off further supply from the reservoir. This movement is not enough to unseat the diaphragm. A bleeder passage expedites balancing of pressure in the brake chambers to that from the brake valve, although it is not large enough to take care effectively of large differences in pressure.

c. If a greater application is made at the brake valve, the relay valve repeats the movement to increase pressure accordingly. If the brake valve is partially released, the drop in pressure above the diaphragm allows the greater brake chamber pressure beneath the diaphragm to lift the diaphragm from its seat. Air may then pass from the brake chamber through holes provided in the diaphragm guide to the exhaust passage. The diaphragm remains unseated until brake chamber pressure equals pressure on top of the diaphragm from the brake valve. The diaphragm is then again deflected downward and seated to prevent further exhaust. Complete release allows all brake chamber pressure to escape. The supply valve spring holds the supply valve seated, closing the passage between the reservoir and the brake chambers when the brakes are released.

d. The relay valve moves very rapidly because only the diaphragm is actuated from the brake valve. Pressure in the brake chambers comes directly from the reservoir. Release is also rapid since air from rear brake chambers is exhausted at the relay valve and does not have to go to the brake valve.

45. Trailer connection.—*a.* When a truck is equipped to haul trailers, two air lines ending in rigidly mounted couplings extend to rear of the truck. The emergency line is brought out to the right hand side of the frame and service line to the left when facing the couplings (see fig. 50). A cut-out cock, located behind each coupling, is closed when the truck is used alone and opened to establish connection with each air line of the trailer when one is used. The emergency line carries air from the truck reservoir to the trailer reservoir, and the service line controls the trailer brakes from the truck brake valve.

b. The fundamental units needed on a trailer are—

- (1) Relay-emergency valve which performs two functions:
 - (a) Relays braking action from tractor to trailer.
 - (b) Produces an automatic brake application in case tractor and trailer become disconnected.
- (2) Reservoir which stores air for applying trailer brakes.
- (3) Brake chamber for each wheel brake on trailer.

c. A flexible hose on the tractor is connected to rigid couplings on the front end of the trailer. A sectional view of a coupling is shown in figure 51. The service line is on the left and the emergency line on the right of the horizontal centerline of all tractors and trailers

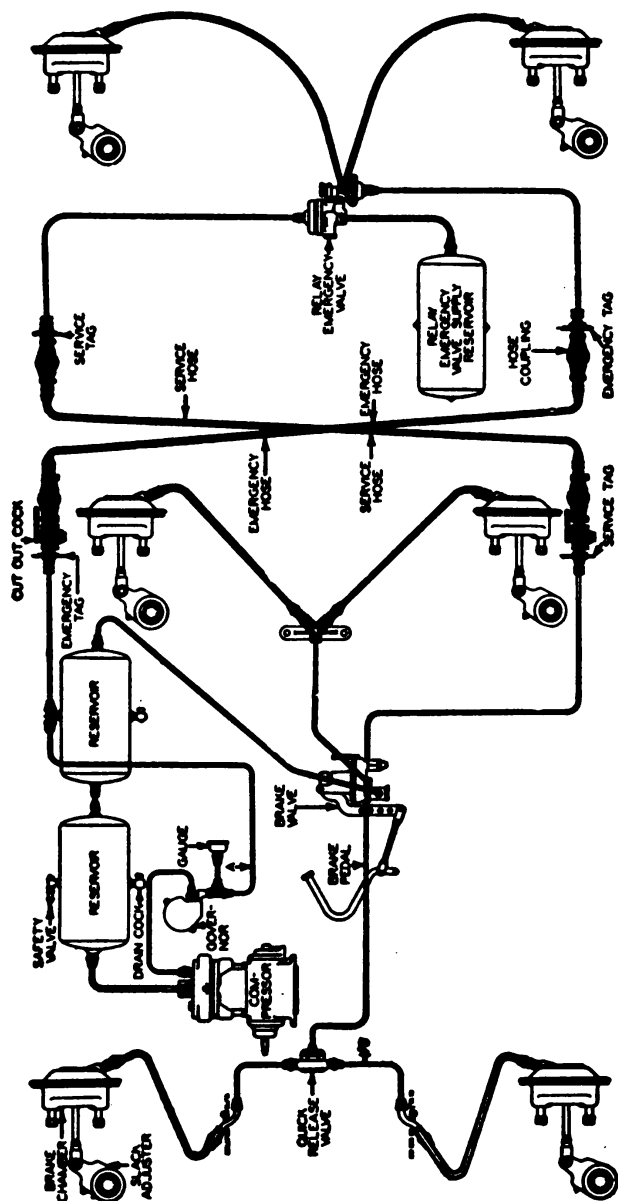


FIGURE 50.—Diagram of air brake system on tractor-trailer combination.

when facing the couplings. Consequently when making air brake connections between vehicles, the flexible hose for emergency and service lines are crossed over each other. These lines are identified by metal tags.

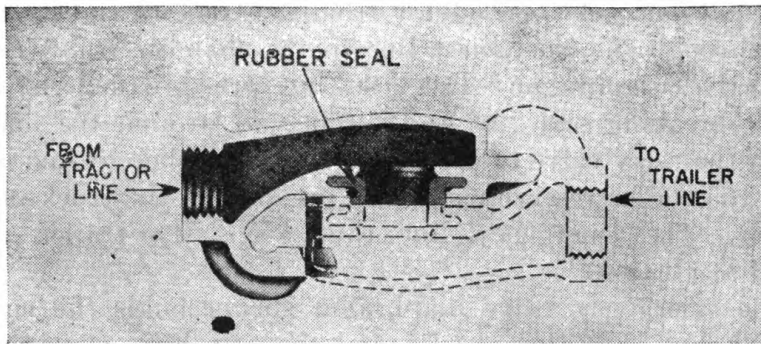


FIGURE 51.—Sectional view of air brake coupling.

46. Relay-emergency valve.—*a.* The relay-emergency valve (fig. 52) consists of a relay valve with an emergency valve substituted for the blanking flange shown in figure 49. The brake chamber connections on the relay valve are plugged and the brake chamber lines are connected to the emergency valve, as shown in figure 52.

b. The trailer reservoir is charged through the relay-emergency valve. When the trailer air lines are connected to the truck or tractor

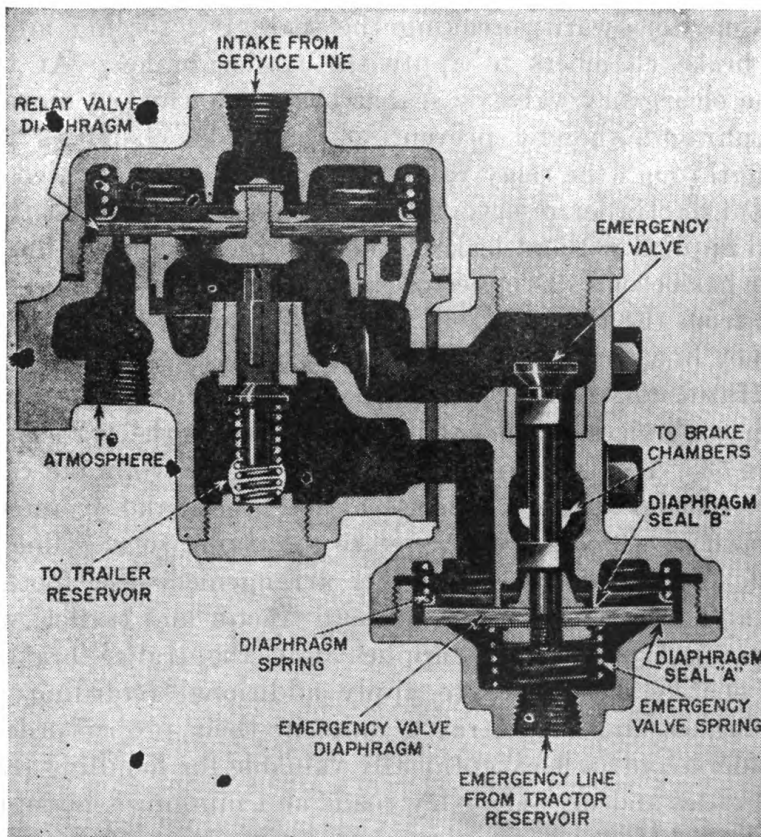


FIGURE 52.—Sectional view of relay-emergency valve.

and the cut-out cocks opened, air from the truck or tractor reservoir passes through the emergency line to the chamber below the emergency valve diaphragm. The resulting pressure deflects the diaphragm, breaking seal "A" and forcing air around the diaphragm through the relay valve to the trailer reservoir, thereby making pressure in the trailer reservoir equal to pressure in the truck or tractor reservoir. The emergency line thus keeps the trailer reservoir charged at all times.

c. The emergency valve diaphragm spring holds the emergency valve diaphragm sealed at "B" and the attached emergency valve from its seat. When the relay portion of the valve operates as described in paragraph 44, trailer reservoir pressure forces air past the unseated emergency valve to the brake chambers for brake application. Brake chambers are exhausted through the relay valve when brakes are released.

d. Should the trailer break away from the truck or tractor or the emergency line hose become disconnected or broken, the pressure below the emergency valve diaphragm is suddenly reduced. Pressure from the trailer reservoir acting on the upper side deflects the diaphragm downward, breaking the seal "B", forcing air upward to the brake chambers to apply the trailer brakes. At the same time the emergency valve is seated by the downward movement of the diaphragm, thereby preventing the brake chambers from exhausting through the relay valve. The diaphragm actuated by pressure from the trailer reservoir, also closes seal "A" so that the brakes are held applied without leakage through the emergency line. After a trailer has become disconnected, trailer brakes are released by draining air from the trailer reservoir or by building up pressure in the emergency line to that in the trailer reservoir.

47. Hand control.—An air brake system for tractor-trailer combination with an independent hand control for the trailer is shown in figure 53. This system operates by means of two brake valves, the regular foot-operated brake valve and the hand-operated brake valve, both of which are connected to the trailer service line through a double check valve. Under this arrangement the foot-operated brake valve applies all brakes on both tractor and trailer, while the hand-operated brake valve applies only the trailer brakes. This system enables the driver to apply additional retarding force on trailer brakes and keeps trailer units in their proper order. This independent control is exceptionally valuable for handling trailers on severe grades and on wet or icy roads and minimizes possibilities of jackknifing. However, in normal braking operations trailer brakes should be used only in conjunction with tractor brakes and should

never be used alone to brake the entire vehicle. The double-check valve in this system prevents air from escaping through the open exhaust valve of whichever brake valve is not being used.

48. Miscellaneous devices.—*a. Air-supply valve.*—(1) An air-supply valve may be installed between the reservoir and the gov-

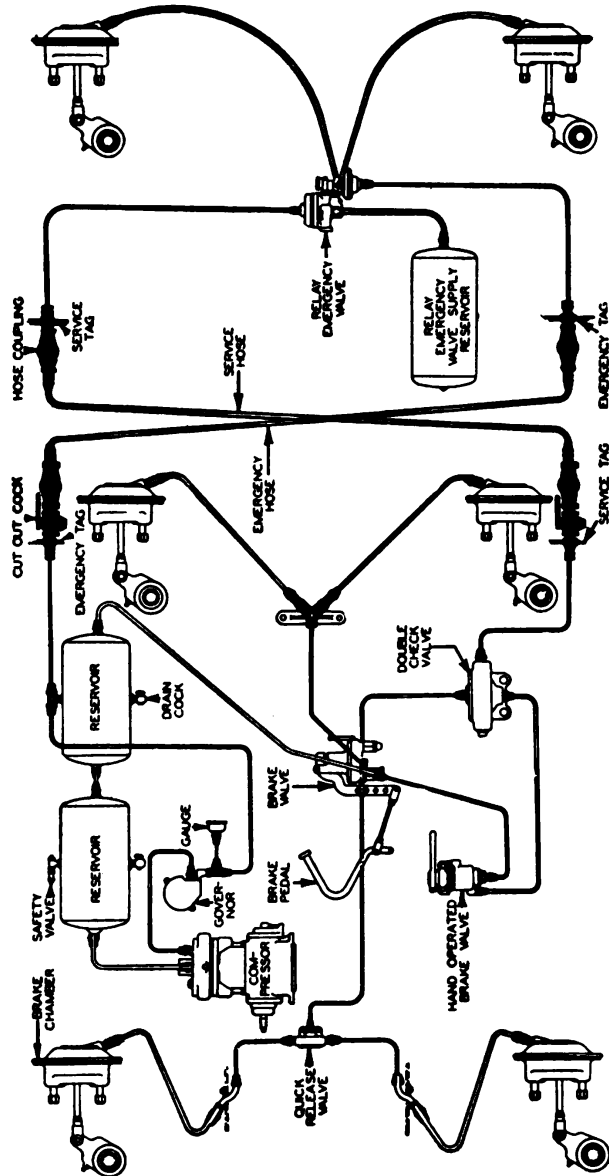


FIGURE 53.—Diagram of air brake system for tractor-trailer combination with independent hand control.

ernor. This valve, operated by a handle, has a side outlet which is threaded so a hose and tire chuck may be attached (see fig. 54). With the handle turned up horizontally, the governor is cut out, the compressor operates continuously to keep the reservoir charged, and

reservoir pressure is passed to the side outlet where it is available for tire inflation, etc. This device makes it possible to inflate the largest pneumatic tires for emergency repairs.

(2) A pipe plug is sometimes found in this valve. It may be removed so that the reservoir may be charged from a shop air line so the engine will not have to be started to operate the compressor.

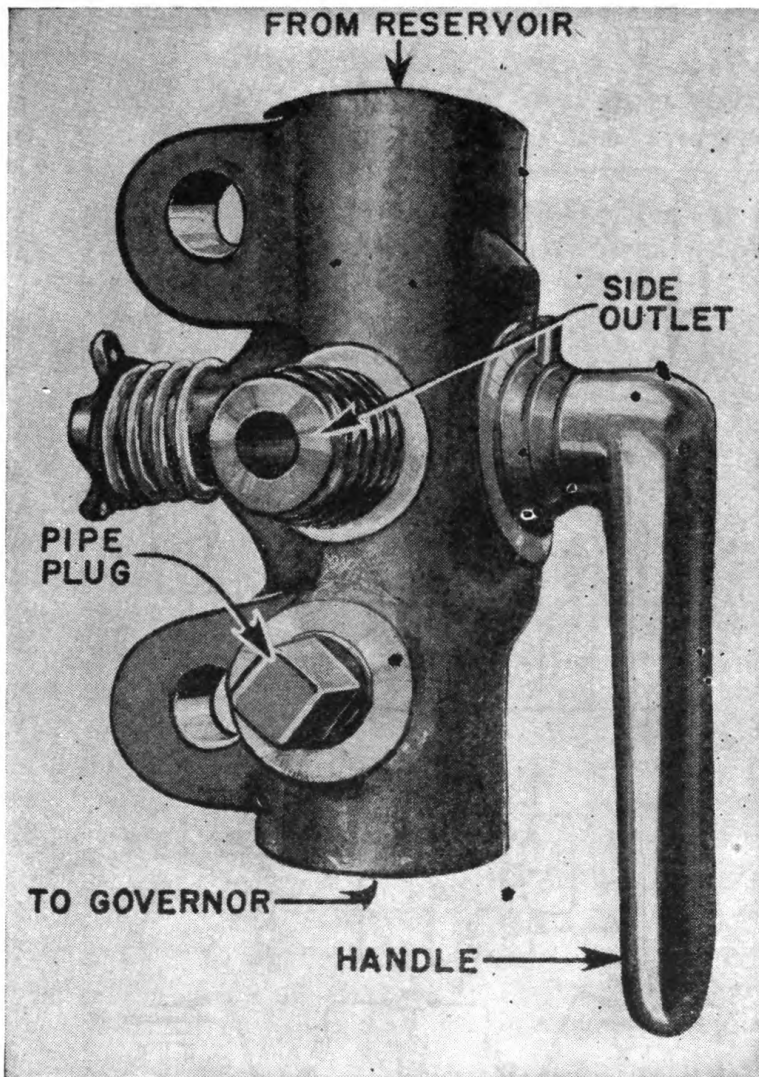


FIGURE 54.—Air-supply valve.

b. Air-pressure gage.—(1) An air-pressure gage on the instrument panel indicates reservoir air pressure and informs the driver of condition of the air-brake system. The gage is connected to a line leading from the reservoir, usually to the line joining the reservoir to the governor.

(2) Before a vehicle is put into motion the air-pressure gage should indicate 70-pounds-per-square-inch pressure in the reservoir so that the air brakes may be effectively applied. If pressure is too low, the engine must be allowed to run until compressor has supplied enough air to the reservoir. If gage reading drops to less than 50 pounds per square inch while vehicle is in motion, vehicle should be stopped and cause of low pressure investigated. Effective braking action cannot be obtained with pressures under 40 pounds per square inch.

c. Low-pressure indicator.—(1) The low-pressure indicator is a warning device that functions automatically and operates a cab buzzer or a light signal whenever air pressure becomes abnormally low. The buzzer or light signal is connected through the ignition switch so that it operates only when the ignition is turned on. The indicator is normally set for 50 pounds which leaves a sufficient margin to insure proper brake control. This device safeguards trucks that operate over exceptionally long steep grades where possibility of excessive or careless braking is increased.

(2) When this device signals a warning, brakes should be sparingly used until pressure is raised by compressor. If pressure remains low even when brakes are little used, vehicle should be stopped and system inspected for leaks or other trouble.

d. Limiting valve.—The limiting valve, by controlling maximum air pressure entering brake chambers, enables the driver to vary the power applied to brakes to meet varying load and road conditions. The force applied to brake shoes is thereby limited so that the wheels will not tend to skid under bad driving conditions. It is installed between the brake valve and the brake chambers.

e. Pressure-regulating valve.—The pressure-regulating valve is used to protect the air brake system against a sudden loss of air pressure when auxiliary devices such as air horns, air steering equipment, windshield wipers, and the like are used. It is installed between the dry (No. 2) reservoir and an auxiliary reservoir used to provide air pressure necessary to operate auxiliary devices. The pressure-regulating valve allows no air to pass through it to auxiliary reservoir until a predetermined pressure has been reached in No. 2 reservoir of the air brake system.

49. Operation.—*a.* Light application of brakes is made by depressing pedal slightly, heavier application by depressing pedal further. Amount of brake application is not governed by pressure on the pedal as it is with mechanical and hydraulic systems but by position of the pedal. How heavy an application should be made for ordinary stops depends upon circumstances in each particular

case such as speed, load, condition of roadway, and kind of stop desired. Removing foot from pedal automatically releases brakes.

b. When the lever of the brake valve is moved to the limit of its stroke an emergency application results which will stop the vehicle in the shortest possible time unless application is so severe that the wheels lock. This heavy application should be reserved for emergencies and not employed in ordinary service braking.

c. The best possible stop is made when the brakes are applied as hard at the very start as the speed and condition of the road will permit, and then eased as speed is reduced so that at the end of the stop only little pressure remains in the brake chambers. Brakes should never be applied lightly at first and heavier as the speed diminishes. This not only makes a longer stop, but final high pressure is apt to produce a rough stop. In easing brakes they should not be repeatedly released and applied because this wastes compressed air.

d. Air control requires less effort to actuate brakes and provides immediate brake application if tractor-trailer unit becomes disconnected. A decided advantage of the air-brake system is that air pressure may also be used to operate air clutches, air gearshifts, air steering, windshield wipers, winches, and to inflate tires.

50. Maintenance.—*a.* Equalization of braking pressure on each braking wheel is obtained by the air-brake system which minimizes skidding and uneven wear on brake linings. Pressure available enables use of a harder, better wearing lining. These factors lengthen periods between adjustments of wheel brakes.

b. Air strainer should be cleaned periodically by removing the hair, washing it in kerosene or gasoline (outdoors), and saturating it with a medium oil. Compressors which are lubricated by oil from the engine require no special attention. Compressors having self-contained lubrication systems should be checked daily and oil added if needed, drained each time the engine crankcase is drained, and refilled with a good grade of summer or winter engine oil, depending on the season. Slack adjusters on air-brake systems should be kept well lubricated by removing the lubricant plug and filling the cavity with chassis lubricant every 6 months or 6,000 miles.

SECTION VI

VACUUM SYSTEM

	Paragraph
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51. Principle.—*a.* In order to understand the principle on which the vacuum system operates, it is necessary to know what a vacuum is and how it can be used. For practical purposes a vacuum may be defined as a space from which air or gas has been partly exhausted.

b. Air, like all matter, has weight. Since air extends upward from sea level for several miles, the weight of this air exerts a pressure, termed “atmospheric pressure,” at sea level of about 15 pounds per square inch, 14.7 pounds per square inch to be exact. This pressure is equally distributed in all directions upon all objects of the earth’s surface.

c. Atmospheric pressure may be used to operate brakes by the creation of a vacuum. Since a vacuum is created by removing air, the pressure within a vacuum is less than that of the atmosphere. A perfect vacuum from which all matter has been removed has no weight or pressure whatsoever. A perfect vacuum is never obtainable although it can be closely approached. Hence, the full force of 15 pounds per square inch atmospheric pressure can never be utilized. If air in a container has been pumped out or evacuated until only 5 pounds per square inch pressure remain, the 10 pounds per square inch differential existing between vacuum pressure and atmospheric pressure may be used to perform work.

d. Vacuum is created in the intake manifold of an internal combustion engine by the pumping action of the pistons. When the vehicle is coasting in high gear with the carburetor throttle fully closed very little air is admitted into the intake manifold so that the pumping action of the pistons reduces the pressure to about 5 pounds per square inch in the manifold. The driver’s foot is taken off the accelerator pedal when he applies the brakes so that about 10 pounds per square inch difference between the vacuum pressure

(5 pounds per square inch) and atmospheric pressure (15 pounds per square inch) are available to operate the brakes.

52. Power cylinder.—*a.* Any chamber connected to the intake manifold will have air exhausted from it when the engine is running. The power cylinder, which contains a piston, depends upon this fact for its operation. A valve operated by the brake pedal is inserted between the cylinder and manifold, as shown in figure 55, to control

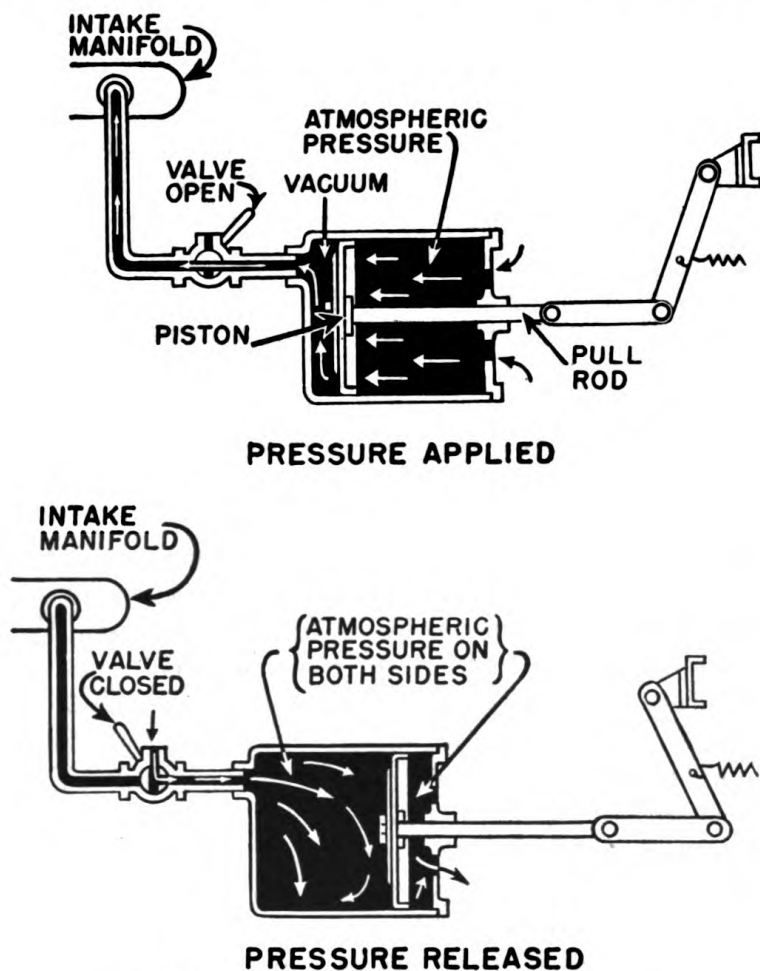


FIGURE 55.—Action of vacuum power cylinder.

the operation of the power cylinder. When the valve is opened air is exhausted from the chamber ahead of the piston. Atmospheric pressure acts on the other side of the piston to exert a powerful pull on the rod attached to the piston. The amount of pull depends upon the area of the piston upon which the pressure acts.

b. When the valve is closed, the chamber ahead of the piston is shut off from the intake manifold and connected to the atmosphere. Air

enters this chamber through the valve and raises the pressure on the front side of the piston to that of the atmosphere, as shown in the lower illustration of figure 55. The pressure is then the same on both sides of the piston so that no pull is exerted on the pull rod and it remains in the release position. The operating principle of the brake valve in a vacuum brake system is similar to that shown in figure 55, although the internal construction and operation are quite different.

c. The vacuum power cylinder is usually fitted with a leather seal on the piston. To keep the seal soft and pliable the power cylinder should be lubricated every 60 days with 2 ounces of oil recommended by the manufacturer (shock-absorber fluid is satisfactory). Oil is injected into the power cylinder by removing the pipe plugs usually located in each end plate. The power cylinder piston rod should be oiled lightly while working back and forth.

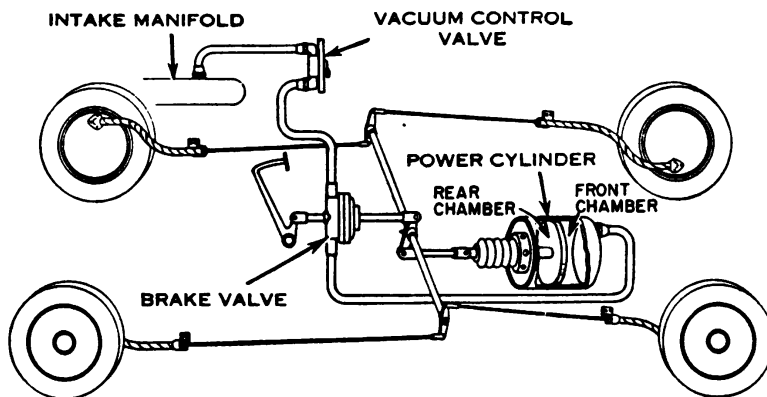


FIGURE 56.—Atmospheric suspended system.

d. Diaphragm power cylinders or chambers are sometimes used when there is room enough for the larger diameter of the diaphragm cylinder and when a shorter stroke is adequate. The diaphragm chamber is relatively cheap and requires no lubrication. The sliding piston cylinder has the advantage of the longer stroke.

53. Atmospheric suspended system.—a. In the power cylinder shown in figure 55, atmospheric pressure exists on both sides of the piston when the valve is closed. A braking system with the power cylinder operated in this manner is known as an atmospheric suspended system (see fig. 56). Depressing the brake pedal opens the brake valve, giving a free passage from the front chamber of the power cylinder to the intake manifold. (The piston pull rod end of the cylinder is designated as “rear” and the opposite end as “front.”) The power of a vacuum cylinder may be applied to either mechanical or hydraulic brake systems.

b. The vacuum power cylinder supplies a considerable force to augment or "boost" the force of the driver's foot. For this reason the vacuum power brake is often called a booster brake. If the vacuum power system fails, direct physical operation of the brakes is always possible.

c. Different conditions and different drivers may require a different degree of power boost. A vacuum control valve between manifold and brake valve permits the driver to control amount of vacuum boost given to brake application. This control valve is usually mounted on the instrument panel and operated by a handle. It is used particularly for passenger cars to prevent overbraking on wet and icy pavements.

d. With an atmospheric suspended system, a charge of air is admitted to the engine manifold every time the brakes are applied, which affects carburetion and also lowers the pressure difference available for operating the brakes. Use of a vacuum reservoir will lessen this condition. Nevertheless, this type of installation is somewhat limited, being adequate for all passenger cars, light trucks, and in some few cases, light trailers.

54. Brake valve.—*a.* The function of the brake valve is to control the action of the vacuum power cylinder. The brake valve used with an atmospheric suspended system includes a diaphragm which is operated by the brake pedal. Figure 57 shows how the diaphragm controls the operation of the brake valve. Figure 57① shows the brake valve in released or "off" position. The diaphragm is seated, closing communication between the vacuum power cylinder and the intake manifold of the engine. Since the cup-shaped disk, which is called the atmospheric valve, is not seated on the diaphragm, the front chamber of the power cylinder is open to the atmosphere. Pressure on the piston is therefore balanced and brakes are held in the release position by the action of their retracting springs.

b. When the operator depresses the brake pedal the atmospheric valve is seated on the diaphragm as shown in figure 57②, closing the atmospheric passage to the power cylinder. As the pedal is depressed further to apply the brakes, the atmospheric valve raises the diaphragm from the intake manifold ports, as shown in figure 57③. Air in the front chamber of the power cylinder then exhausts to the intake manifold. Atmospheric pressure on rear of piston then assists in applying the brakes.

c. Vacuum in the intake manifold tends to keep the diaphragm seated at all times and the force applied to the brake pedal must be large enough to overcome this suction in order to raise the diaphragm

AUTOMOTIVE BRAKES

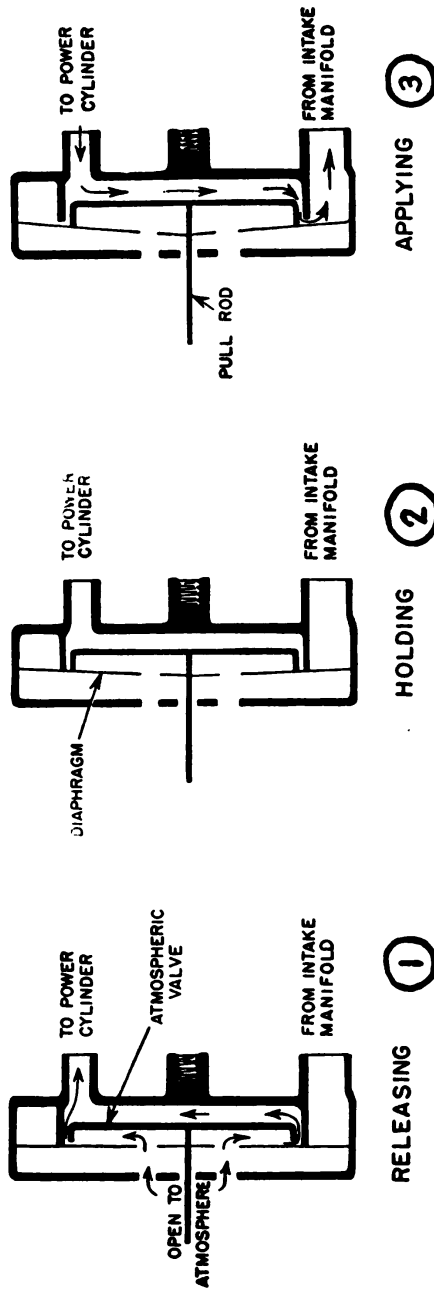


FIGURE 57.—Diagram of brake valve used with atmospheric suspended system.

from its seat. Pressure is therefore needed to depress the pedal which gives a "feel" to the brake application. Since the brake valve is pulled by the brake pull rod in the same direction as the brakes are applied, any physical effort exerted at the pedal is not lost but is transmitted directly to the brake mechanism through the pull rod.

d. A hydraulic brake valve operated by hydraulic pressure rather than pedal position may be used for operating the power cylinder when hooked up with a hydraulic brake system. The use of a vacuum booster with a hydraulic system is illustrated in figure 58. When the pedal is depressed the resulting pressure of the brake fluid from the master cylinder operates the hydraulic brake valve which controls the amount of boost given to the brake application by the power

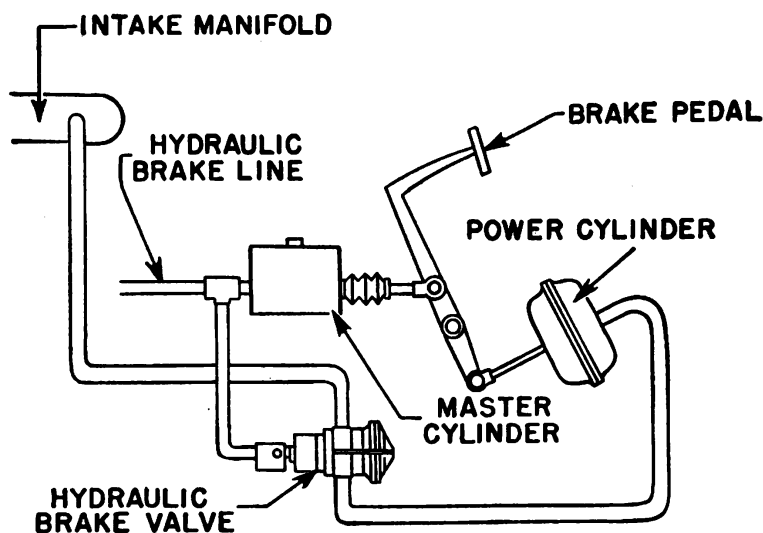


FIGURE 58.—Diagram of hydraulic brake valve used with atmospheric suspended system.

cylinder. The hydraulic brake valve shown in figure 58 has a reactionary control, as described in paragraph 57.

55. Vacuum suspended system.—*a.* In order to apply the brakes faster and to take full advantage of the vacuum available for operating the brakes, a vacuum system has been developed in which vacuum is present on both sides of the piston when the engine is running and brakes are released. Such a vacuum system of power braking, known as a vacuum suspended system, is shown in figure 59.

b. A check valve maintains a vacuum within the system even after the engine is stopped by closing the intake manifold when pressure in the manifold rises above the vacuum pressure within the system. A vacuum reservoir is usually required so that a substantial source of vacuum is available. Once air is pumped out of the reservoir

through the intake manifold, the resulting vacuum is diminished only by operating the power cylinder.

c. With the brake pedal in the release position, there is a passage through the brake valve from the vacuum reservoir to the rear chamber of the power cylinder (see fig. 59). Since the front chamber is connected to the vacuum reservoir at all times, the piston is suspended in a vacuum when it is in the release position.

d. When the brake pedal is depressed to apply the brakes, the brake valve closes the vacuum passage to the rear chamber, and opens a passage to the atmosphere through the brake valve. Air is admitted only to the rear chamber, which is the pressure chamber in this illustration. The piston is thus forced to the front of the cylinder to apply power to the braking system. With the vacuum sus-

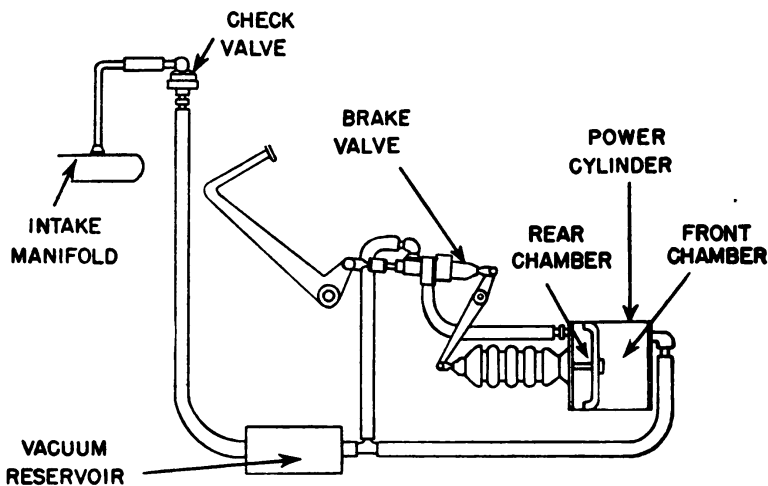


FIGURE 59.—Vacuum suspended system.

pended system, the brakes may be applied without admitting a charge of air to the reservoir so that the available vacuum is not reduced.

e. When the brake pedal is released, the air in the rear chamber of the power cylinder is drawn into the reservoir through a passage opened in the brake valve, equalizing pressure on each side of the piston and permitting the brakes to be released by their retracting springs.

f. All force applied to the brake pedal is transmitted directly to the brake system since the brake valve is contained within the pull rods that operate the brake mechanism. The entire valve may be moved with the pull rods to apply the brakes by physical effort when the power cylinder becomes inoperative.

56. External brake valve.—*a.* Operation of the external brake valve used with the vacuum suspended system is quite simple as may

be seen from the sectional view of the valve shown in figure 60. In the release position the rear or atmospheric valve is seated and the vacuum valve is open so that the vacuum reservoir is connected to the rear chamber of the power cylinder. The air in the rear chamber of the power cylinder is exhausted through the vacuum valve to the reservoir and from there to intake manifold of the engine. The piston in the cylinder is then balanced in a vacuum since the front chamber is directly connected to the reservoir and exerts no pull on the brake mechanism.

b. When the brakes are applied the control rod is pulled by the external linkage to the brake pedal so that it seats the vacuum valve and opens the atmospheric valve. Vacuum is then shut off from the rear chamber of the power cylinder, and air enters through the air strainer past the atmospheric valve to the power cylinder. The amount of air admitted to the rear chamber of the power cylinder depends

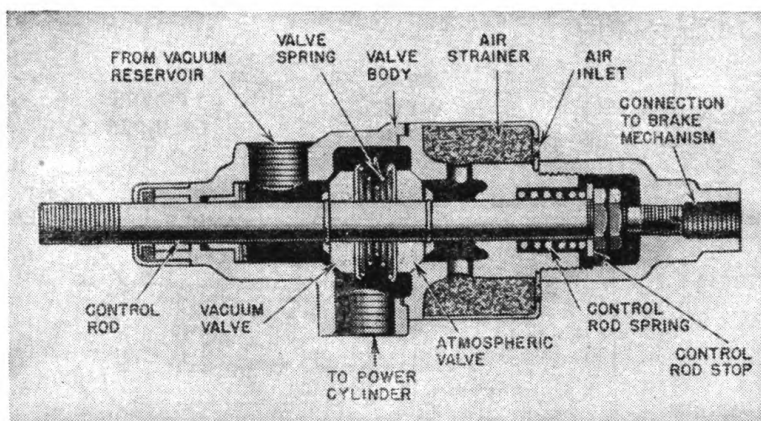


FIGURE 60.—Sectional view of external brake valve.

upon how far the brake pedal is depressed. If the operator stops forward movement of the brake pedal, the valve casing or body, which is connected to the brake mechanism, will be moved forward sufficiently by action of the power cylinder to close the atmospheric valve and prevent any additional air going to the power cylinder. The vacuum valve remains closed due to pressure of the valve spring and pressure in the power cylinder. In this position the brakes are held applied until the operator releases pressure on the foot pedal. Any additional braking may be accomplished by pressing the foot pedal further to repeat the cycle of operation. When the brakes are fully applied any further force applied to the pedal compresses the control rod spring to keep the control rod stop against the valve body, and is transmitted through the valve body to the brake mechanism. To release the brakes pressure is removed from the brake pedal, and through the action of

the internal spring the vacuum valve is lifted from its seat so that the air present in the rear chamber of the cylinder exhausts to the intake manifold. This again balances the power cylinder piston in a vacuum and the brakes are released by the action of their retracting springs.

57. Reactionary brake valve.—*a.* The reactionary brake valve incorporates the valuable feature of reactionary control, which gives a light but firm pedal reaction against the driver's foot that increases in proportion to degree of brake application. This reaction aids in controlling vehicle brakes and permits a smoother, more gradual brake application. The required pedal pressure is increased only to the extent that appreciable pedal "feel" is necessary.

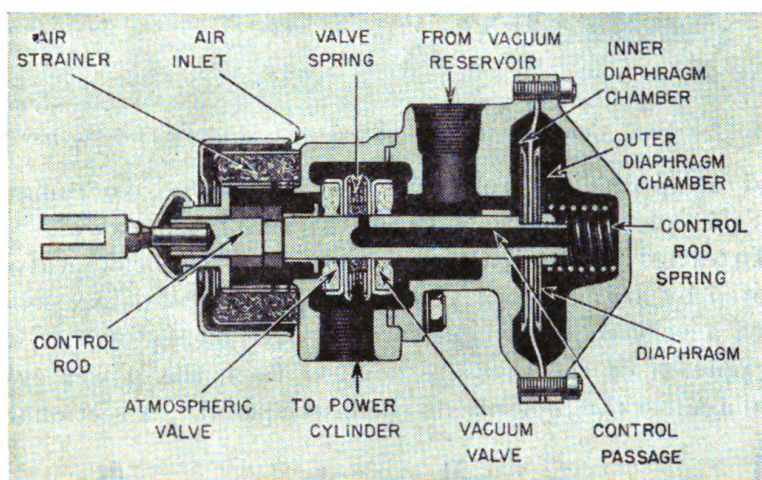


FIGURE 61.—Sectional view of reactionary brake valve.

b. The valve operates similarly to the external brake valve, except for the diaphragm that causes the reaction. In released position as shown in figure 61, vacuum is present on both sides of the diaphragm since both chambers are connected by passages to the vacuum reservoir. The vacuum valve is open and a balanced vacuum is present on both sides of the power cylinder piston. In applied position, the valve control rod is pushed in by the external linkage to the brake pedal so that it seats the vacuum valve and opens the atmospheric valve. Air then enters through the air strainer and around the atmospheric valve to the power cylinder and applies the brakes.

c. A control passage in the valve control rod leads from between the two valve disks to the outer diaphragm chamber. Therefore the outer diaphragm chamber has the same pressure as the pressure chamber of the power cylinder. The inner diaphragm chamber is connected by a passage to the reservoir connection. Therefore the

opposing pressures acting on the diaphragm are the same as the opposing pressures working on the power cylinder piston. The diaphragm, which is mounted on the control rod, exerts a reaction against the driver's foot exactly in proportion to amount of power application, but greatly reduced in amount because of the relatively small area of the diaphragm compared to that of the power cylinder piston. The brakes

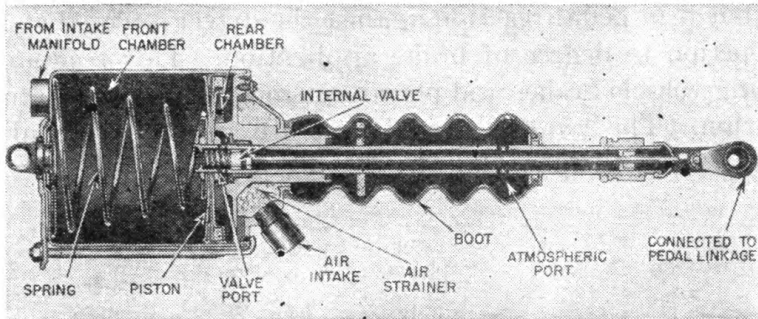


FIGURE 62.—Sectional view of internal brake valve incorporated within power cylinder.

are held in applied position and released by the reactionary brake valve in the same manner as with the external brake valve.

58. Internal brake valve.—*a.* The internal brake valve, which is operated by an ingenious pedal linkage, provides reactionary control with a very compact construction. By means of this linkage a certain portion of the pressure derived from the power cylinder is balanced against the pressure on the brake pedal. A sectional view of

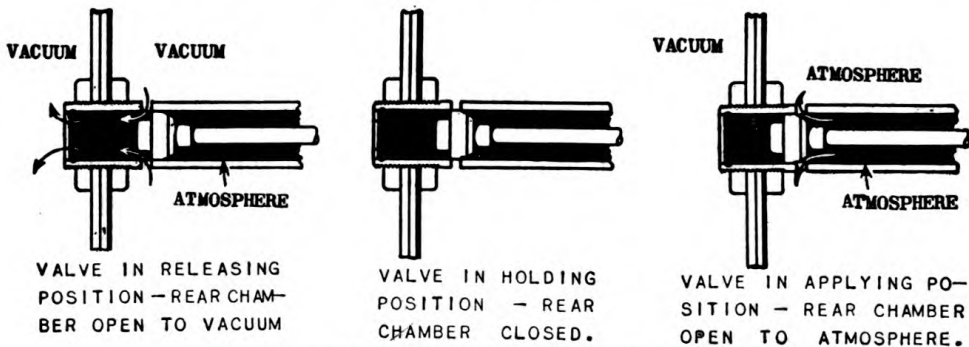


FIGURE 63.—Operation of internal valve.

the internal brake valve, which is incorporated within the power cylinder, is shown in figure 62. The front chamber of the power cylinder is connected to the intake manifold. The front and rear chambers are interconnected through the center of the piston and the valve port when the internal valve is in released position.

b. Operation of the internal valve is shown in figure 63. When the brake pedal is depressed the internal valve is moved so that it covers

the valve port, thereby disconnecting the rear chamber of the power cylinder from the front chamber. When the valve passes the valve port, the rear chamber is opened to the atmosphere through the atmospheric port and air strainer. With atmospheric pressure on the rear side of the piston and a vacuum on its opposite side, the piston is forced to move forward and applies the brakes through a pedal linkage.

c. When the power cylinder piston moves forward, the internal valve will cover the valve port and assume a holding position. Any further movement of the brake pedal would move the valve to applying position and admit additional air at atmospheric pressure until a balance is again reached. The braking force obtained from the power cylinder is thrust onto the pedal linkage which applies the brakes. A portion of this force balances against the brake pedal to give the driver's foot "feel" of the braking action.

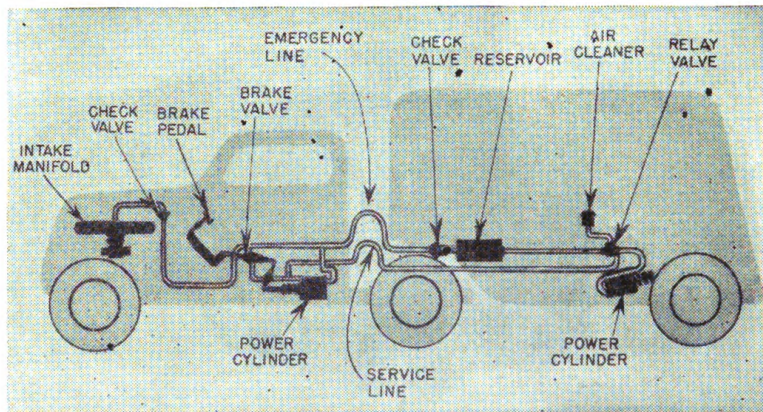


FIGURE 64.—Vacuum braking system on tractor-trailer combination.

59. Trailer equipment.—*a. Brake valve.*—The brake valve is placed close to the power cylinder on a tractor so that quick brake application results when the pedal is applied. However, in a tractor-trailer combination the brake valve is comparatively far away from the trailer brake system. If the tractor brake valve alone operated both tractor and trailer power cylinders, the difference in length of the vacuum lines would delay the trailer brakes. As a result the tractor brakes would be applied before the trailer brakes, causing the trailer to "jackknife" or run up on the tractor.

b. Relay valve.—(1) To avoid jackknifing a relay valve is installed on the trailer so that it is just as close to the trailer power cylinder as the tractor brake valve is to the tractor power cylinder (see fig. 64). The trailer power cylinder is then operated directly from the relay valve which relays the action of the tractor brake valve.

(2) Independent power cylinders operated by a master relay valve may be mounted directly on each braking wheel of six-wheel trucks or trailers. A relay valve may be used with either brake valve or an independent hand control valve.

(3) A sectional view of a relay valve adapted for use with a vacuum suspended system on tractor and trailer is shown in figure 65. In a vacuum suspended system, vacuum is present on both sides of the piston in the power cylinder and on both sides of the relay diaphragm and in both the service and emergency lines connecting tractor to trailer when the engine is running and the brakes are released.

(4) When the operator opens the brake valve atmospheric pressure enters the relay valve from the service line, depressing the diaphragm. This operates the valve linkage which snaps shut the vacuum valve

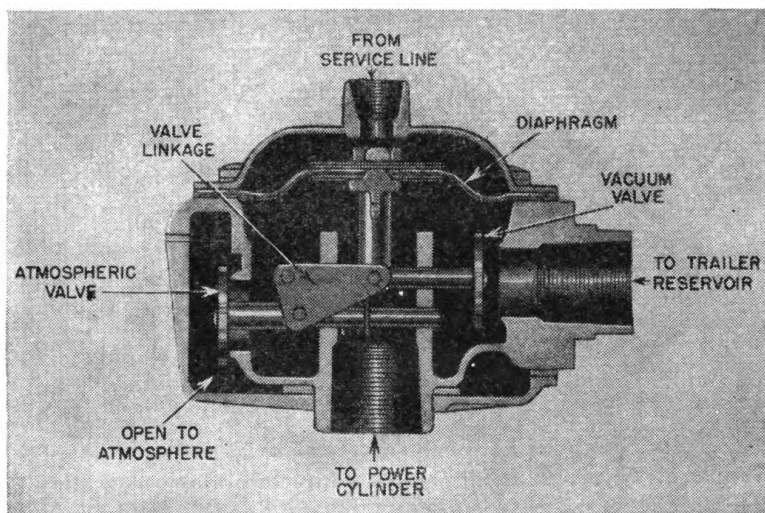


FIGURE 65.—Sectional view of relay valve (vacuum system).

and at the same time snaps open the atmospheric valve which instantly admits atmospheric pressure to the power cylinder, causing the piston to move forward and apply the brakes.

(5) When the operator closes the brake valve vacuum is again restored in the service line. Spring tension on the valve linkage then forces the atmospheric valve closed and the vacuum valve open. Vacuum then exists on both sides of the cylinder piston permitting immediate release of the brakes.

c. Reservoir.—To get the best trailer brake action it is naturally advisable to have a secondary source of vacuum close to the trailer power cylinder. This may be provided by a vacuum reservoir on the trailer. Such a reservoir is essential to provide emergency brake application in event of an accidental break-away. A check valve is used

in the emergency line from the tractor to hold the vacuum in the trailer brake system. The vacuum reservoir should be large enough to hold the trailer brakes fully applied for 15 minutes (time specified by regulations of the Interstate Commerce Commission). The reservoir volume necessary to do this increases with size and number of power cylinders on the trailer. The reservoir tank must exhaust the air from the cylinders to apply the brakes on atmospheric suspended trailer systems. Therefore considerably larger reservoirs are required than are needed on vacuum suspended trailer systems to prevent appreciable lowering of the vacuum in the reservoir.

d. Hand control.—When the trailer is heavily loaded it will tend to run up on the tractor because the heavier load requires a larger braking force. This might jackknife a vehicle, particularly on a down grade, and cause it to get out of control. To prevent this the trailer brakes are independently operated by use of a hand-operated brake valve connected to the intake manifold in the same manner as the foot-operated brake valve. This hand control is usually mounted on the steering column and operated by a short hand lever.

e. Synchronizer valve.—A synchronizer valve is used to prevent the tractor brakes from braking faster than the brakes on the trailer when all of the brakes on the vehicle are operated together from the brake valve. This might happen if there are differences in the design of the tractor and trailer braking systems (that is, tractor brakes might be self-energizing and trailer brakes not self-energizing). The synchronizer valve, which is actually an adjustable relay valve, is used in place of the relay valve to remedy such a condition. Adjusting the spring pressure on the diaphragm of the synchronizer valve synchronizes and balances the brakes of the trailer with those of the tractor. By changing the adjustment to reduce the spring pressure on the synchronizer diaphragm within the valve, it is possible to speed up trailer brake action and to maintain greater trailer braking force.

60. Combinations.—*a.* There is a relay valve for every vacuum power braking combination. In addition to the relay for vacuum suspended trailers and vacuum suspended tractors, there is a conversion relay for a vacuum suspended tractor combined with an atmospheric suspended trailer and a universal relay for an atmospheric suspended tractor combined with either a vacuum or atmospheric suspended trailer.

b. Interchanging tractors and trailers when some are equipped with air brakes and some with vacuum power brakes is possible with the pneumatic relay valve. The relay valve may be mounted on either tractor or trailer, depending on the fleet equipment. For fleets with

many air braked tractors and a few trailers with vacuum power brakes, the valve is usually mounted on the trailer. When there are only a few tractors with air brakes and many trailers with vacuum power brakes, the valve is generally mounted on the tractor, eliminating necessity of any change on the trailer. A hydraulic relay valve may be used in a similar manner to combine a hydraulic system on a tractor with a vacuum system on a trailer.

SECTION VII

ELECTRIC SYSTEM

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61. General.—A brake which is set into operation electrically is sometimes used. The lay-out of the electric brake system which operates from the storage battery or the electrical system is quite simple. Wiring replaces the rods, cables, and tubings used in other types of brakes. One of the chief advantages from a trailer standpoint is that only electric wires are needed as connection between tractor and trailer.

62. Controller.—A bronze lever within the controller connected by linkage to the brake pedal (fig. 66) acts as a rheostat switch. The controller is provided with electrical terminals to convert it in the electric brake circuit. As the brake pedal is depressed the bronze lever comes in contact with leaves of varying lengths and completes the electric circuit from the battery to an electromagnet in the brake. Electric current is then supplied to the electromagnet, the amount depending on the number of leaves contacted by the bronze lever. When the brake is fully depressed all the leaves are in contact with the bronze lever and the maximum amount of current flows to the brake.

63. Electric brake.—*a.* A sectional view of the electric brake which is placed on each wheel is shown in figure 67. The armature revolves with the brake drum and is kept in constant contact with the electromagnet by means of flat springs. When the brake pedal is depressed the current flows from the controller to the brake and through a coil of copper wire in the magnet, setting up a magnetic field and causing the magnet to attract the armature. The farther the footpedal is depressed, the greater is the amount of current that reaches the magnet and the tighter the magnet clings to the armature. This attraction of the magnet to the armature causes the magnet which can revolve within a limited arc, to start turning with the

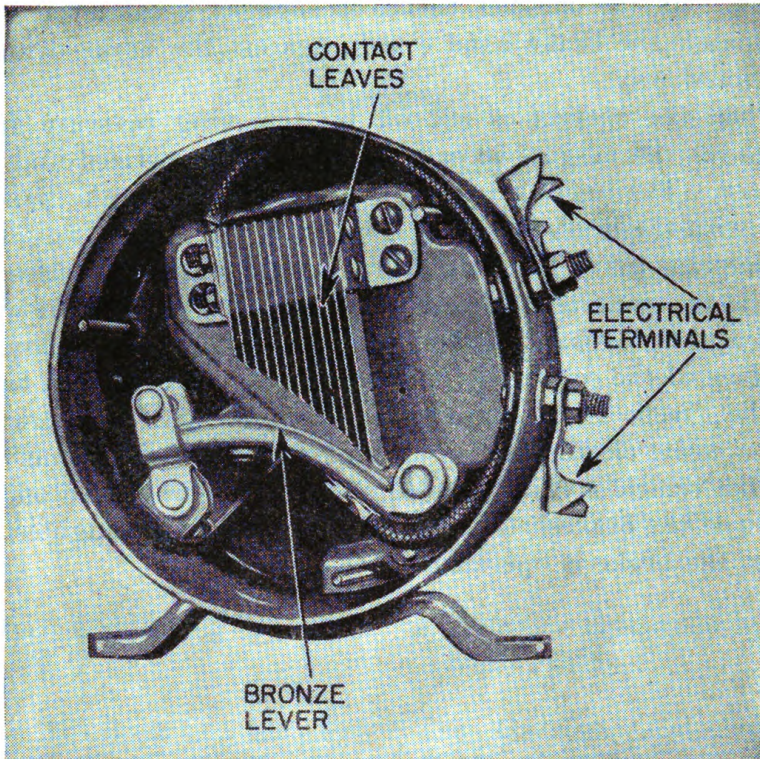


FIGURE 66.—Controller for electric brake.

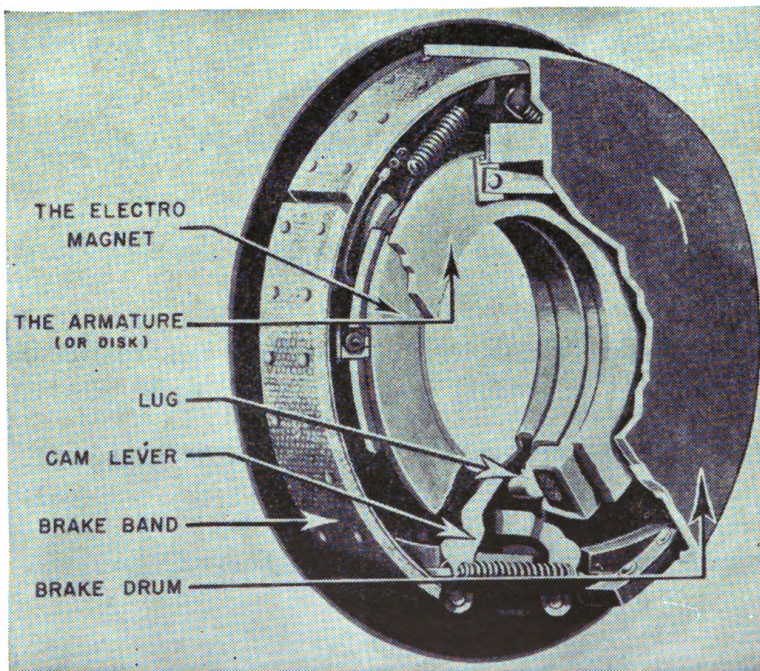


FIGURE 67.—Sectional view of electric brake.

armature. As the magnet turns, it engages a camlever which in turn expands the brake band evenly against the brake drum in the conventional way.

b. When the current is cut off by removing pressure from the brake pedal, the magnet in each brake is demagnetized and remains stationary. The brake return springs release the brake bands from contact with the brake drums.

c. The principle of the electric brake permits use of a self-adjusting feature to compensate for lining wear. As the brake band wears the electromagnet moves a little further to drive the brake lining against the surface of the drum. An automatic stop on the brake band prevents the rivets from coming into contact with the drum after excessive wear, eliminating danger of scoring of the drum.

d. If the vehicle is standing still and the current turned on, there is no action of the brakes. If the wheel revolves in the slightest degree, however, the brake is operated.

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APPENDIX

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[A. G. 062.11 (10-17-40).]

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Chief of Staff.

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The Adjutant General.

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